

# Land use change and prediction in the Baimahe Basin using GIS and CA-Markov model

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**Abstract.** Using ArcGIS and IDRISI, land use dynamics and Shannon entropy information were applied in this paper to analyze the quantity and structure change in the Baimahe Basin from 1996 to 2008. A CA-Markov model was applied to predict the land use patterns in 2020. Results showed that farmland, forest and construction land are the dominant land use types in the Baimahe Basin. From 1996 to 2008, areas of farmland and forest decreased and other land use types increased, with construction land increasing the most. The prediction results showed that the changes in land use patterns from 2008 to 2020 would be the same with those from 1996 to 2008. Main changes are the transiting out of farmland and forest and the transiting in of construction land. The order degree of the whole basin goes on decreasing. Measures of farmland protection and grain for green projects should be adopted to enhance the stability of land use system in the Baimahe Basin in order to promote regional sustainable development.

## 1. Introduction

Studies and predictions on land use changes at a basin scale are meaningful to reasonable exploitation and management of land resources, improvement of eco-environment and sustainable development of water resources of the basin. Nowadays, there are many models applied by studies and predictions on land use changes<sup>[1]</sup>. In this context, CA-Markov model firstly uses the Markov model to predict land use patterns, and then uses the Cellular Automation (CA) model to conduct spatial correction on the prediction result. This model not only retains the priority of the Markov model on long term prediction, but also synthesizes the capability of the CA model on simulating complex temporal-spatial land use changes, which contributes to better simulations and predictions of land use changes both temporally and spatially<sup>[2-3]</sup>.

The Baimahe River is one of main tributaries of the Nansihu Lake, which is the largest freshwater lake in North China. Fast development on economy and society in the Baimahe Basin has caused great changes on land use patterns, which has affected the hydrological processes and ecological

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environment of the Nansihu Lake. It is of great importance to study and predict the land use patterns in the Baimahe Basin. Using GIS and IDRISI Andes 15.0 software, this paper studied the changes of land use patterns from 1996 to 2008 in the Baimahe Basin and applied the CA-Markov model to predict the land use pattern in 2020. We hope to provide science-based suggestions on rational utilization of land resources and on sustainable development in the Baimahe Basin.

## 2. Study area

The Baimahe Basin locates in Jining city, Shandong province. It originates from north of Zoucheng city and falls into the Dushan Lake in Luqiao town. The length of the Baimahe River is 60km, and the area of the basin is 1 099km<sup>2</sup>. It is on the transition belt between the Southeast Shandong hills and the West Shandong Plain. The elevation varies from 30m to 544m. This basin enjoys a warm temperate continental monsoon climate with an annual average precipitation of 708.2mm and an annual average temperature of 14.7°C. As an important component of the regional economic development strategy “One Body, Two Wings”, this basin has a great potential for further economic and social development.

## 3. Data and method

### 3.1 Remote sensing data

Two sets TM images in 1996 and 2008, covering the Baimahe Basin with a resolution of 30m×30m were downloaded from <http://datamirror.csdb.cn/>. Man-machine interactive visual interpreting method was then used to interpret the above TM images into land use patterns with the support of the ArcGIS9.3 and Erdas9.2. On the basis of current land use classification standards of China and combined with the practical situation of the Baimahe Basin, there are 6 land use types in the basin, i.e., farmland, forest, grassland, construction land, waters and unused land.

### 3.2 Land use change indexes

Land use changes in a basin are mainly represented by changes in quantity and in structure. Land use changes in quantity are represented by changes in area and in speed. Land use area changes refer to area changes of different land use types from the beginning of the research period to the end of this period; land use changes in speed can be measured by single land use dynamic index ( $K$ ) and comprehensive land use dynamic index ( $LC$ ). The meanings of these indexes can be found in references<sup>[4]</sup>.

The information entropy theory proposed by Shannon has been widely used in researches on land use structure changes. The equation of regional land use information entropy ( $H$ ) can be learned also from reference<sup>[4]</sup>. Relative land use information entropy ( $J$ ), which is also named equilibrium degree, is the ratio of the practical entropy in the biggest entropy. The bigger is the value of  $J$ , the more equilibrium is the regional land use patterns.

### 3.3 CA-Markov model

The basic principle of the Cellular Automation (CA) model is that the cellular state of the next moment is a function of the neighboring cellular's present state. In this paper, the cellular was defined as a grid with a resolution of 30m×30m and the cellular space was the Baimahe basin. Each cellular had 6 probable states, i.e., the 6 land use types. Using ArcGIS9.3 and IDRISI Andes15.0, CA-Markov model was used to predict the land use patterns of the Baimahe Basin in 2020:

- Data format conversion and reclassification. The formation of land use patterns in 1996 and 2008 were firstly changed from vector to grid, then grid to ASCII files, and ASCII files were finally transited to IDRISI type. Land use types were reclassified in IDRISI Andes15.0.
- Markov analysis. State transition matrix and transfer area matrix were obtained by overlying the land use patterns in 1996 and in 2008. The database of the CA-Markov model was established in this step.

- Establishment of the transition suitability image sets. This is the key step of the CA-Markov model. Driving factors were selected to formulate the transition suitability image sets which can be used as limiting conditions of the CA-Markov model.
- Building CA filters and determining cycle times. CA filters of 5×5 were built and 12 cycle times were determined to predict the land use.

## 4. Results and analysis

### 4.1 Quantity and structure changes analysis

The man-machine interactive visual interpreting method was applied to obtain the land use patterns of the Baimahe basin from TM images in 1996 and 2008. Kappa indexes in 1996 and 2008 were 0.87 and 0.83, respectively, meaning that the interpretation results were convincing.

**Table 1** .Range and speed of land use change in the Baimahe basin during 1996-2008

Land use types	Farmland	Forest	Grass land	Construction land	Waters	Unused land
Year 1996 km <sup>2</sup>	672.921	213.20	16.861	136.56	43.628	16.763
Ratios	61.18%	19.38%	1.53%	12.42%	3.97%	1.52%
Year 2008 km <sup>2</sup>	645.98	158.086	17.392	195.89	45.728	36.866
Ratios	58.73%	14.37%	1.58%	17.81%	4.16%	3.35%
1996-2008 Net Changes km <sup>2</sup>	-26.941	-55.114	0.531	59.321	2.101	20.103
Single Land Use Dynamic Index	-0.33%	-2.15%	0.26%	3.62%	0.40%	9.99%

The prominent land use types of the Baimahe Basin in 1996 and 2008 were farmland, forest and construction land (Table 1). These three land use types occupied more than 90% of the basin. The ratio of the forest in total area of the basin was bigger than that of the construction land in 1996, while the ratio of the construction land was the bigger one in 2008. Farmland and forest both showed decreasing trends during 1996-2008. In contrast, grass land, construction land, waters and unused land all suffered increasing trends.

**Table 2** .Transition matrix of 6 land use types in the Baimahe Basin during 1996-2008

1996 \ 2008	Farmland	Forest	Grass land	Construction land	Waters	Unused land
Farmland	566.92	8.69	1.96	57.94	7.24	3.23
Forest	26.60	106.27	2.83	7.40	0.89	14.09
Grass land	3.86	1.64	8.81	0.27	1.45	1.36
Construction land	15.93	2.25	0.12	176.97	0.48	0.14
Waters	4.50	0.17	2.51	1.79	36.73	0.03
Unused land	0.87	5.25	1.12	0.46	0.48	28.70

Combined with Table1 and Table2, The in-transition speed of the unused land and construction land and the out-transition speed of forest were faster than other transitions. The main performances of land transitions were farmland transiting to construction land, forest transiting to farmland, unused land and waters transiting to farmland. In this context, the transition from farmland to construction land was the most obvious. The comprehensive land use dynamic index during 1996-2008 was 0.62%, implying that the land use index in each year equalled to 0.62% and the changes were faint.

The value of  $H$  was 0.49 and the value of  $J$  was 0.63 in 1996; while in 2008, the value of  $H$  was 0.53 and the value of  $J$  was 0.68, revealing that from 1996 to 2008, the land use orderly degree in the Baimahe Basin decreased, while the equilibrium degree of the whole basin increased. The distribution of all land use types has been more dispersed.

#### 4.2 Land use prediction based on CA-Markov model

The results of the land use pattern prediction in 2020 based on CA-Markov model were shown in Table 3.

**Table 3** .Land use change statistics in the Baimahe Basin in 2020

Land use types	Farmland	Forest	Grass land	Construction land	Waters	Unused land
Year 2020	618.70	124.28	17.35	244.81	47.24	47.56
Ratios	56.25%	11.30%	1.58%	22.26%	4.29%	4.32%
2008-2020 net changes(km <sup>2</sup> )	-27.28	-33.80	-0.04	48.92	1.51	10.69
Single land use dynamic index	-4.22%	-21.38%	-0.25%	24.98%	3.31%	29.00%
Comprehensive land use dynamic index				0.46%		
Land use information entropy				0.54		
Land use equilibrium degree				0.69		

According to Table3, the ratios of 6 land use types in 2020 will be similar with that in 2008 and the changing trends of the 6 land use types during 2008-2020 will also be similar to that during 1996-2008 except grass land: construction land will be the largest increasing type, 48.92 km<sup>2</sup> more than that in 1996, followed by the unused land. The out-transition area of the forest will be the largest, followed by that of the farmland; and the grass land will not change much. Compared with the changing speed during 1996-2008, the speed during 2008-2020 will be higher. The single land use dynamic index of the forest will be -21.38%, meaning that forest will be the fastest reduced land use type. The information entropy will be 0.54, bigger than that during 1996-2008, implying that the orderly degree will decrease while the equilibrium degree will go on increasing.

According to the prediction results, the land use transitions during 2008-2020 will mainly include farmland transiting to construction land, farmland transiting to waters and unused land, forest transiting to farmland, grass land, construction land and unused land, and grass land transiting to farmland. The above transitions will occupy 89.89% of all the transition areas. Farmland and forest will mainly transit out to other types, while farmland will mainly transit to construction land, occupying 85.68% of the whole out-transition areas, and 52.48% of the forest will mainly transit out to farmland. Construction land will be mainly transited in by other types, with the farmland being the largest source, occupying 85.92% of total in-transition areas of the construction land.

## 5. Conclusions and discussions

### 5.1 Conclusions

- The prominent land use types of the Baimahe Basin during 1996-2008 were farmland, forest and construction land. The areas of farmland and forest both decreased, while the areas of the other land use types increased, with the construction land suffered the largest increment. Land use transitions principally took place from farmland to construction land, forest to farmland, forest to unused land and waters to farmland. The spatial pattern of all 6 land use types suffered in a dispersing trend, as the general order degree decreased during 1996-2008.
- According to the prediction result of the CA-Markov model, the prominent land use types during 2008-2020 will still be farmland, forest and construction land. The changing trends of the land use types will be similar with those during 1996-2008. Land use transitions will take place mainly in the out-transition of the farmland and forest and in the in-transition of the construction land. The changing speed of the land use types will be enhanced in some degree. The land use information entropy will increase and the general order degree will continue decreasing, leaving the land use system being unsteady.

### 5.2 Discussions

The prediction results in 2020 follows the land use changes during 1996-2008, implying that there is certain feasibility in respect of the utilization of the CA-Markov model on the prediction of land use changes. However, more driving factors on land use changes should be considered to construct the transition suitability image set, for the purpose of enhancing accuracy of the prediction.

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