

The Prediction of LUCC in Ejina Oasis based on Markov model

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Abstract—In order to predict the changes of Land Use/Cover Change (LUCC) in Ejina Oasis (EO) after water resources redistribution in Heihe River, the remote sensing images in 2002 and 2006 were selected, a new set of land use categories was developed and the Markov model was employed. Results show that: From 2010 to 2022, it still have a large change in the land use of Ejina Oasis, the area of farmland, forestland, grassland, water, construction land continue to increase, among which water is the fastest increased than the other increased land use type, the area of increase is 56.88km². At same time, the area of unused land continue to decline, among which saline land is the fastest reduced than others reduced land use type, the area of reduce is 23.70km². But the area of increment and decrement are both gradually lessen. The ecological environment of Ejina Oasis still be a state of recovery from 2010 to 2022, the proportion of farmland, forestland, grassland and water have a significant increase, while sand, saline land have a obvious decrease, and the structure of land use in 2022 is more reasonable than it in 2010.

Keywords- Ejina Oasis, LUCC, Water Resources Redistribution in Heihe River, Markov model

I. INTRODUCTION

LUCC plays a vital role in regional, social and economic development and global environmental changes [1]. It is one among the most important alterations of the Earth's land surface [2]. Moreover, LUCC transformation processes have accelerated since the Second World War [3-5]. Consequently, understanding and predicting the causes, processes and consequences of LUCC have become a major challenge. In the international community, the application of LUCC can be summarized as three core issues: dynamic analysis of process, driving forces, and global and regional models of LUCC [6-9] by using RS and GIS technology. In China, it includes dynamic information access, process simulation, development trends, driving mechanism and eco-environmental effects and others [10-13]. Nevertheless, there are relatively few studies in EO. To make up this blankness and contribute to restoring the vulnerable ecosystem in EO, LUCC in EO was predicted based on the remote sensing images in 2002 and 2006 and exertion related Markov model, which could be useful for local governments to make land use policies.

II. MATERIALS AND METHODS

A. Study area

EO is a typical representative of oasis in arid areas. It is located in the extreme arid climate zone in China. Though located in both sides of eastern and western of Ejina River with an annual average temperature of 8.3°C and yearly average rainfall of only 50~70mm, the yearly average evaporation is over 3000mm. The surface water is so scarce that the run-off and groundwater become the main water resource in EO. The research scope of this paper (Fig. 1) covers the EO totally with an area of about 15,800 km².

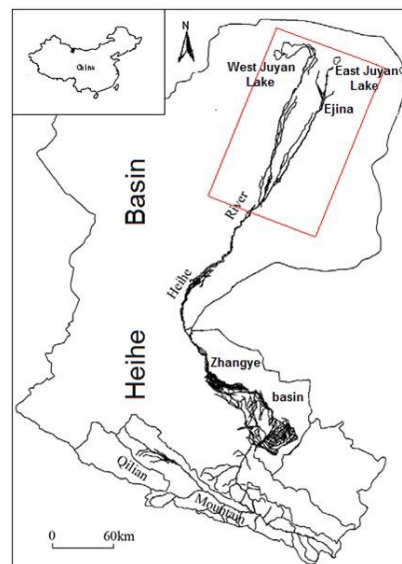


Figure1. Location of study area

B. Data and Methods

This paper adopted images in 2002 and 2006, 1:50,000 topographic map and administrative division map of the area studied which were provided by Chinese Academy of Sciences. A new set of land use categories was developed by modifying the US Geological Survey Land-use/Land Cover Classification System [14] applicable to the study area, including 6 classes and 19 sub-classes and by taking full account of these investigations in the field (TABLE I). Based on the remote sensing images and the software of ERDAS IMAGING 8.5, LUCC information of the study area was acquired. Then an

overlay analysis of different factors' layers was done with the ARCGIS 9.0 supporting, and regional LUCC process was predicted according to all these data and the Markov model.

TABLE I. THE CLASSIFICATION OF LAND USE IN STUDY AREA

Land use type		Sub-type		Land use type		Sub-type	
No	Name	No	Name	No	Name	No	Name
1	Farmland	11	Paddy field	4	Water	43	Reservoir and pond
		12	Dry land			44	Flood plain
2	Forest land	21	Forestry land	5	Construction land	51	Urban land
		22	Shrub land			52	Rural settlements
		23	Sparse woodland			53	Other built-up
3	Grassland	31	High coverage grassland	6	Unused land	61	Sand
		32	Moderate coverage grassland			62	Saline land
		33	Low coverage grassland			63	Gobi
41	River	64	Bare rock and gravel				
42	Lake						

C. Markov model

Markov process is a kind of special random moving from one state to another state at each time step. A first-order Markov model is a model of such a system in which probability distribution over next state was assumed to only depend on current state (and not on previous ones) [15-17]. This characteristic of Markov process is appropriate to application change of land use structure, because dynamic change of land use also possesses the properties of Markov process under certain conditions: 1) within a certain region, different land use types may be transformed into each other; 2) mutual conversion process between land use types includes many incidents which are difficult to be described precisely by a special function, and 3) during study periods, average transfer state of land use structure is relatively stable and accordant with requirements of Markov Chain. The mathematics expression of Markov model is expressed as follows:

$$S^{(t)} = (S_1^{(t)}, S_2^{(t)}, \dots, S_m^{(t)}) \tag{1}$$

In this formula, $S^{(0)}$ is initial state vector of the land use.

$$P = (P_{ij}) = \begin{pmatrix} P_{11} & P_{12} & \dots & P_{1n} \\ P_{21} & P_{22} & \dots & P_{2n} \\ \dots & \dots & \dots & \dots \\ P_{n1} & P_{n2} & \dots & P_{nm} \end{pmatrix} \tag{2}$$

In this formula, P is original transfer probability matrix of land use, P_{ij} was probability of the i th type land transformation into the j th type land from prophase to telophase; n was land

use type of the study area. P_{ij} should meet the following conditions:

$$0 \leq P_{ij} \leq 1 \quad (i, j = 1, 2, 3, \dots, n) \tag{3}$$

$$\sum_{i=1}^n P_{ij} = 1 \quad (i, j = 1, 2, 3, \dots, n) \tag{4}$$

$$S^{(t)} = S^{(t-1)} P = S^{(0)} P^{\Delta t} \tag{5}$$

In this formula, Δt is a state transition from the initial step-size.

III. RESULTS

A. The simulation and examination of Markov process

First, by using LUCC matrix (TABLE III), the step length 4a of land use change matrix were calculated, and the annual matrix of land use change from 2002 to 2006 (TABLE IV) were obtained. Second, the percentage of the area of each land use type in 2002 was selected as the initial state vector. Third, Markov basic equation (the formula 5) was used to simulate the land use type in 2006. Last, did a contrast between the actual percentage of the area of each land use type in 2006 and the value of simulation (TABLE II). It can see from the TABLE II that the value of simulation and actual are very close. Error rate used the formula (6) calculate of construction land was the biggest in all land use, its value was only 0.42%. And error rate of the other land use type were all smaller than it of construction land. Therefore, it was feasible use Markov process to predict the land use change in Ejina Oasis.

$$E = \sqrt{\sum_{i=1}^n \left[\frac{(x_i - x_i')^2}{x_i} / \sum_{i=1}^n x_i \right]} \times 100\% \tag{6}$$

In this formula, x_i is the point of fitting the state variables, x_i' is the results of fitting the state variables.

TABLE II. EXAMINATION OF LAND USE STRUCTURE BY USING MARKOV PROCESS SIMULATION (KM²,%)

Type	actual value	proportion	Simulated area	proportion	E
farmland	49.26	0.31	48.98	0.31	0.03
forestland	988.46	6.26	987.54	6.25	0.02
grassland	2372.95	15.02	2371.69	15.01	0.02
water	115.08	0.73	113.77	0.72	0.10
Construction land	16.38	0.10	14.22	0.09	0.42
sand	504.34	3.19	508.78	3.22	0.16
saline land	55.29	0.35	58.46	0.37	0.34
Gobi	11496.47	72.76	11491.85	72.73	0.03
Bare rock and gravel	202.46	1.28	202.25	1.28	0.01

B. A dynamic simulation and prediction in Ejina Oasis by Markov model

According to the theory of Markov model, the percentage of the area of each land use type in 2006 was selected as the initial state vector to predict the land use change in study area. And with the help of the annual matrix of land use change (TABLE IV), the software of MATLAB and Markov basic equation (the formula 5), the results of land use change prediction from 2010 to 2022 were obtained to analyze the land use change in Ejina oasis in the future (TABLE V).

It can be seen from the TABLE V: from 2010 to 2022, the areas of farmland, forestland, grassland, water and construction land are all increased, but the areas of increment are gradually lessened. For example, the value of increment of forestland is 22.12 from 2010 to 2014, it is 22.12 from 2014 to 2018, and it is 18.96 from 2018 to 2022; the value of increment of grassland is 18.96 from 2010 to 2014, it is 14.22 from 2014 to 2018, and it is 9.48 from 2018 to 2022 and so on. On the contrary, the area of unused land is reduced, among which the area of decrement of sub-types are gradually shrink. For example, the value of decrement of sand is 52.14 from 2010 to 2014, it is 44.24 from 2014 to 2018, and it is 37.93 from 2018 to 2022. From 2010 to 2022, the water is the fastest increased than the other increased land use type, the value of increase is 56.88 km², the relative speed of increase is 1.42. Follow are farmland and construction land, the value of increase is 14.22 km² and 3.16 km², the relative speed of increase is 1.26 and 1.20 respectively. And the grassland is the slowest increased type, the value of increase is 42.66 km², the relative speed of increase is 1.02. While the saline land is the fastest reduced than others reduced land use type, the value of reduce is 23.70 km², the relative speed of reduce is 0.44. Follow are sand, the value of reduce is 134.31 km², the relative speed of reduce is 0.70. And the area of bare rock and gravel and gobi remain a little change or unchange. In a whole, the structure of land use in 2022 is more reasonable than it in 2010, the proportion of farmland, forestland, grassland and water have a significant increase, while sand, saline land have a obvious decrease.

IV. DISCUSSIONS AND CONCLUSIONS

From 2010 to 2022, it still have a large change in the land use of Ejina Oasis, the area of farmland, forestland, grassland, water, construction land continue to increase, the area of unused land continue to decline. But the level of utilization and development of unused land are getting lower and lower. It is the reason that gobi, bare rock and gravel have a large proportion in the unused land type, and it is difficult to utilize and develop, while sand, saline land have a very small proportion which only have a part to be developed.

The structure of land use in 2022 is more reasonable than it in 2010, the proportion of farmland, forestland, grassland and water have a significant increase, while sand, saline land have a obvious decrease, it show ecological environment of Ejina Oasis still be a state of recovery. But the whole process of prediction has not shown the undulate characteristics of LUCC. It is the reason that condition must be follow when Markov model has been applied to predict the future trend of LUCC, which be an assumption that the influencing factors of LUCC do not change or remain a relatively stable state in a

short time. And it has an uncertainty for using Markov model to predict the future trend of LUCC in a long time. Therefore, a viable and long-term recovery plan should be mapped out, which must follow strategy and experience had already be obtained in the process of the oasis recovery. Meanwhile, we should do a study about the measures and experience of the oasis recovery, discussing and comparing the measures and experience for a long time, to restore Ejina Oasis fastly and effectively.

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TABLE III. THE CHANGE MATRIX OF LAND USE TYPES FROM 2002 TO 2006 IN STUDY AREA (KM²)

2006 \ 2002	farmland	forestland	grassland	water	Construction land	sand	saline land	Gobi	Bare rock and gravel
farmland	41.99	0.12	0.45	0.38	0.00	0.07	0.07	0.00	0.00
forestland	0.00	937.81	16.87	3.83	0.00	0.00	0.00	0.00	0.00
grassland	4.44	27.34	2284.65	15.89	0.70	2.57	1.17	0.00	0.00
water	0.15	0.47	2.13	88.70	0.00	0.00	0.00	0.00	0.00
Construction land	0.00	0.10	0.05	0.00	14.36	0.11	0.00	0.00	0.00
sand	0.00	22.15	56.29	0.00	0.00	496.33	0.00	1.85	0.00
saline land	3.60	1.02	10.96	5.93	0.00	0.53	54.54	0.21	0.00
Gobi	0.00	0.00	3.45	0.00	1.08	5.75	0.00	11490.08	0.00
Bare rock and gravel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	202.44

TABLE IV. THE ANNUAL MATRIX OF LAND USE CHANGE FROM 2002 TO 2006 IN STUDY AREA

2006 \ 2002	farmland	forestland	grassland	water	Construction land	sand	saline land	Gobi	Bare rock and gravel
farmland	0.9937	0.0007	0.0026	0.0022	0.0000	0.0004	0.0004	0.0000	0.0000
forestland	0.0000	0.9946	0.0044	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000
grassland	0.0005	0.0029	0.9944	0.0017	0.0001	0.0003	0.0001	0.0000	0.0000
water	0.0004	0.0013	0.0058	0.9925	0.0000	0.0000	0.0000	0.0000	0.0000
Construction land	0.0000	0.0017	0.0009	0.0000	0.9955	0.0019	0.0000	0.0000	0.0000
sand	0.0000	0.0096	0.0244	0.0000	0.0000	0.9652	0.0000	0.0008	0.0000
saline land	0.0117	0.0033	0.0357	0.0193	0.0000	0.0017	0.9276	0.0007	0.0000
Gobi	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.9998	0.0000
Bare rock and gravel	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

TABLE V. PREDICTION OF LAND USE CHANGE BASED ON MARKOV MODEL IN STUDY AREA(KM²,%)

Type	2010		2014		2018		2022		relative speed
	Area	proportion	Area	proportion	Area	proportion	Area	proportion	
farmland	55.3	0.35	60.04	0.38	64.78	0.41	69.52	0.44	1.26
forestland	1015.99	6.43	1038.11	6.57	1060.23	6.71	1079.19	6.83	1.06
grassland	2400.13	15.19	2419.09	15.31	2433.31	15.4	2442.79	15.46	1.02
water	135.89	0.86	156.43	0.99	173.81	1.1	192.77	1.22	1.42
Construction land	15.8	0.1	17.38	0.11	17.38	0.11	18.96	0.12	1.2
sand	445.58	2.82	393.44	2.49	349.2	2.21	311.27	1.97	0.7
saline land	42.66	0.27	31.6	0.2	25.28	0.16	18.96	0.12	0.44
Gobi	11488.69	72.71	11480.79	72.66	11472.89	72.61	11464.99	72.56	1
Bare rock and gravel	202.25	1.28	202.25	1.28	202.25	1.28	202.25	1.28	1