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Study on Land Use Change in Arid and Semiarid Region Based on GIS and RS

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Abstract: Regional land use dynamic monitoring analysis is an important part of land use study. It provides basis for rational use of regional land and government's macro-control. In this study, Minqin County in Gansu province of China was adopted as the study area. Based on the two Landsat TM image sets in 1991 and 2009, the land use changes of Minqin in 18 years were monitored and analyzed dynamically by the computer automatic interpretation and visual interpretation method. According to the land-use map, the transition matrix was used to study the changes of different kinds of land use types in Minqin. The results show that the desert area in Minqin has increased by 643.67 km^2, including 541.35 km^2 saline soil and 233.12 km^2 vegetation area. It indicates that the vegetation has been severely damaged. The vegetation area has decreased by 441.87 km^2, most of which was transformed to deserts and saline soil. In this study, the Markov model was applied to predict the land use trends of Minqin in next decades. It pointed out that the desert area would increase by 0.17% each year, the vegetation area would be deteriorated before getting better and the city subdivision would be increased by 0.028% each year. This study provides scientific basis for the eco-environmental control of Arid and Semiarid Region.

Key words: Land-use change, GIS, RS, transition matrix, minqin

INTRODUCTION

The land use/cover changes (LUCC) is an important part of the global environmental change research which is also the basis for in-depth study. Therefore, LUCC and its environmental effects have attracted widespread concern in academia (Zeng *et al*., 2008; Zhang *et al*., 2006). Land use change is the joint production of natural factors and socio-economic factors. It exhibits varying characteristics in different time and spatial scales. Different exponential models have been proposed to examine the land use strength in a certain period and the dynamic characteristics of land use change in different periods (Li *et al*., 2007; Bao and Zhao, 2011). Due to the advantages in data acquisition, processing and spatial expression, remote sensing and geographic information technology have been widely used in land use/cover studies and achieved fruitful results in both research and application (Meng *et al*., 2003; Liang *et al*., 2010; An and Ding, 2000; Duan *et al*., 2005). However, because of the complexity of the drive factors and temporal and spatial characteristics in LUCC studies, a number of uncertain problems are to be further studied in theoretical system and technical support system. However, because of the complexity of the drive factors and temporal and spatial characteristics in LUCC studies, a number of uncertain problems in theoretical system and technical support system need further research.

This study selected Minqin county in Gansu province of China as the experiment region which is one of the typical Arid and Semiarid Region. In the recent 20 years, the climate of Minqin tends to be arid, leading to the gradual disappearance of oasis and deterioration of the ecological environment. This region has been become one of the four major sand storm sources in northern China. Thus, this study discussed the land use changes and its trends in Minqin based on RS and GIS technology. It is a scientific basis for the local ecological construction as well as references for the sustainable development in other arid and semi-arid areas.

OVERVIEW OF THE STUDY AREA

Minqin County is located in the northeast of the Hexi Corridor in China which is the downstream of the Shiyang River Basin. It is situated at longitude 103'~104' and latitude 38'~39'. The altitude of Minqin ranges from 1298 to 1936 m and its average altitude is 1400 m. This area is made up of three basic landforms which are deserts, hills and plains. In the east, the west and the north, it is surrounded by the Tengger Desert and Badain Jaran Desert. This area exhibits the characteristics of evident continental desert climate, such as hot in summer and cold in winter, scarce rainfall, adequate sunlight, high temperature difference between day and night etc., The average annual rainfall is only 110 mm, while the evaporation is up to 2644 mm. Currently, the total land area of Minqin is about 16,000 km^2, while oasis is only 9% of the total area.

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IMAGE PROCESSING AND INFORMATION EXTRACTION

Land use change monitoring process: According to Technical Rules of Land Use Survey in China (TCADC, 1984) and the actual situation of the study area, six land use types were listed in this study which were desert, heavy saline soil, vegetation, city subdivision, light saline soil and waters. The two sets of ETM+images in 1991 and 2009 with good quality were adopted in the experimental study. Its spatial resolution was 30m and the images were not covered by cloud.

For Minqin, there are four steps in its land use change monitoring process which are shown in Fig. 1:

- **Step 1: Data processing:** It included image preprocessing and classification of land use types. The image preprocessing used the atmospheric and geometric correction on the two sets of ETM+images, namely, cropping the image region according to the administrative boundaries of Minqin County
- **Step 2: Image conversion processing:** Principal component conversion processing was implemented on the two sets of ETM+images after preprocessing. Then the PC 1, 2, 3 principal components were extracted to compose the new color images
- **Step 3: Image classification and interpretation:** Supervised classification processing and artificial interpretation were carried out for the images obtained in step 2
- **Step 4: Results analysis:** Do verification and analysis on supervised classification results and artificial interpretation results

Supervised classification and artificial interpretation correction: Supervised classification process was completed using ENVI software. Firstly, this study selected the typical regions for each land type and established samples to be supervised classified according to the interpretation symbols established in image processing and the spectral characteristics of objects in the images (Mei *et al*., 2001). Secondly, the maximum likelihood method was used for supervised classification (Wang, 2006). The process of culling and re-classification should be done for the small patches produced in classification process, where the small patches would be incorporated into big categories based on clustering processing and unqualified small patches would be filtered out. Thirdly, artificial visual interpretation would be implemented to extract land-use type information according to expert experiences. Finally, the results of supervised classification and interpretation would be synthesized based on ArcGIS. And quantitative information on a variety of land-use types would be obtained using statistical analysis tools. Meanwhile, change detection would be done by the Union tool of

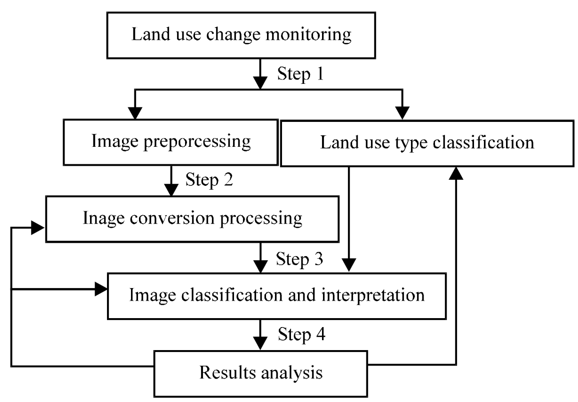

Fig. 1: Land use change monitoring process of minqin in china

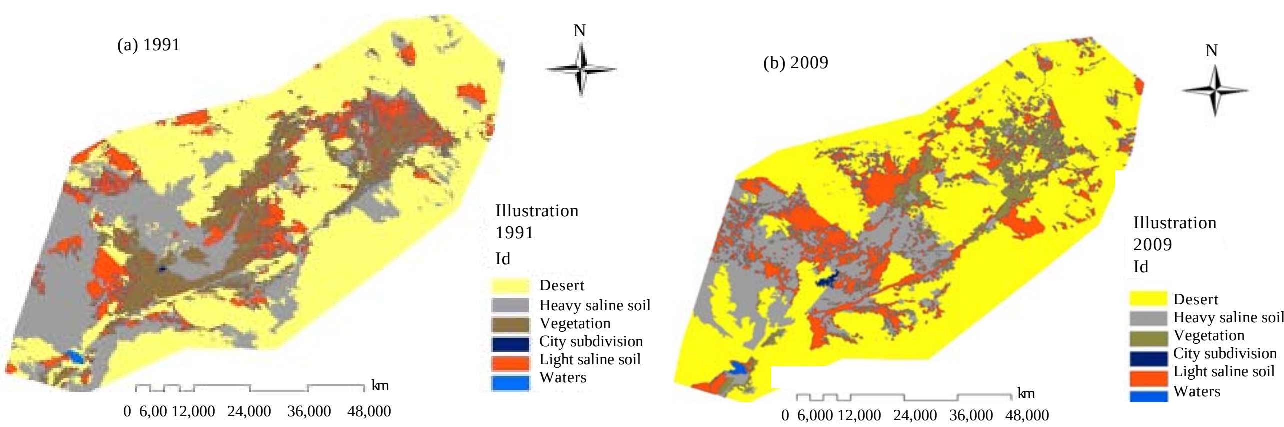

Fig. 2(a-b): Land use type classification of (a) Minqin region in China (1991 and 2009) and (b) Land use type classification result of 2009

ArcGIS. The above steps enabled the purpose of dynamic monitoring on the study area and got results in the classification thematic map of land use change. The results are shown in Fig. 2a,b.

RESULTS ANALYSIS AND PREDICTION

Change of land area in minqin: According to statistical analysis on the classification results of the bi-temporal images, the study obtained the change results of land use and cover in 1991 and 2009 and the 18 years' land use changes. They are shown in Table 1. Table 1 shows that the 18 years' land use and cover change was large in Minqin. At the same time, each land type had a certain degree of increase or decrease. In the six types of landforms, desert increased by 10% (643.67 km^2), city subdivision increased by 8.11 km^2, light saline soil increased by 240.46 km^2, while heavy saline soil decreased by 7% (450.66 km^2) and vegetation decreased by 7% (441.87 km^2). According to the viewpoint of changing amount and changing rate, vegetation and city subdivision had the maximum variation which embodied in the rapid decrease in vegetation areas and the substantial increase in urban areas. With the increasing urban population in recent years, the economic development and construction caused serious vegetation destruction.

Transition matrix: The transition matrix between land use types of Minqin during the 18 years was obtained through overlapping calculation and statistical analysis on the two sets land use classification maps by ArcGIS. This matrix comprehensively reflects regional land use change and various land use types, as shown in Table 2. This transition matrix shows that the majority of the desert increase is degenerated from heavy saline soil and vegetation and the decrease of vegetation is mainly transformed into saline soil and city subdivision. After 18 years, the vegetation was seriously damaged. Therefore, something should be done to manage saline soil and make full use of land resources. By planting drought-resistant, anti-sandstorm and adaptable plants in saline soil areas, some desertified land may be turned to oasis.

Trend forecast of land use change in minqin: In this study, the Markov matrix model was adopted to predict trends of land use change. One condition of the Markov matrix model is to select two matrices (Wang, 2005; Tian and Yu, 2002; Wang *et al*., 2002). Matrix A composed by the percentage of each type of land use in 2009 is considered as the initial matrix, as shown in Table 3.

The selected land use type transition probability matrix is shown as follow:

$$P = P_{ij} = \begin{vmatrix} P_{11}, P_{12}, \ldots, P_{1n} \\ P_{21}, P_{22}, \ldots, P_{2n} \\ P_{n1}, P_{n2}, \ldots, P_{nn} \end{vmatrix}$$

$$P_{ij} = \frac{C_{i-j}}{LU_i} \tag{1}$$

where, P_{ij} indicates the probability of transforming land type i into type j; C_{i-j} indicates the land area of transforming type i into type j; LU_i indicates the total area of land type i at the initial period. Each element of the transition matrix must meet the following two conditions: (1) $0<P_{ij}<1$, that is, all the elements are non-negative; (2) $\sum P_{ij} = 1$, that is, the sum of each row is 1.

Table 1: Land use change of minqin during 1991-2009

	1991		2009		Land use change	
Land type	Area (km^2)	Proportion (%)	Area (km^2)	Proportion (%)	Changing amount (km^2)	Changing rate (%)
Desert	3208.96	51.73	3852.64	62.11	643.67	20.06
Heavy saline soil	1477.13	23.81	1026.47	16.55	-450.66	-30.51
Vegetation	810.32	13.06	368.45	5.94	-441.87	-54.53
City subdivision	2.33	0.04	10.44	0.17	8.11	348.07
Light saline soil	694.14	11.19	934.60	15.07	240.46	34.64
Waters	10.45	0.17	10.74	0.17	0.29	2.78

Table 2: Transition matrix of land use change of minqin in 1991-2009

Land type	Desert	Heavy saline soil	Vegetation	City subdivision	Light saline soil	Waters	Total in 1991
Desert	2655.00	166.70	60.31		325.00	1.96	3208.96
Heavy saline soil	608.05	377.70	42.98	4.90	422.84	0.65	1477.13
Vegetation	293.43	269.31	190.90	3.28	53.37	0.02	0810.32
City subdivision	0.07			2.26			0002.33
Light saline soil	295.50	212.53	74.25		111.43	0.42	0694.14
Waters	0.59	0.26			1.95	7.69	0010.45
Total in 2009	3852.64	1026.47	368.45	10.44	934.60	10.74	

Table 3: Initial matrix

Land type	Desert	Heavy saline soil	Vegetation	City subdivision	Light saline soil	Waters
A	0.621059	0.165471	0.059395	0.001683	0.150661	0.001731

Table 4: Area transition probability matrix of minqin land use types in 1991-2009

Land type	Desert	Heavy saline soil	Vegetation	City subdivision	Light saline soil	Waters
Desert	0.827370	0.051948	0.018794	0.000000	0.101277	0.000610
Heavy saline soil	0.411642	0.255698	0.029096	0.003317	0.286257	0.000440
Vegetation	0.362116	0.332350	0.235585	0.004047	0.065862	2.468160
City subdivision	0.030043	0.000000	0.000000	0.969957	0.000000	0.000000
Light saline soil	0.425707	0.306178	0.106967	0.000000	0.160529	0.000609
Waters	0.056459	0.0248802	0.000000	0.000000	0.186603	0.735886

Table 5: Prediction percentages of land use types using the Markov model

Land type	2027 (%)	2045 (%)	2063 (%)
Desert	66.78	69.47	72.58
Heavy saline soil	14.05	13.23	13.89
Vegetation	4.66	4.24	4.41
City subdivision	0.24	0.30	0.35
Light saline soil	13.87	16.09	17.88
Waters	14.84	22.48	27.08

After selecting the area transition matrix (Table 4) of land use types of Minqin in 1991-2009, calculate the area transition probability matrix (Table 5) according to Eq. 1.

According to the no-aftereffect of the Markov process, the state probability vector P(n) at any time in the study area can be inferred from the transition probability matrix Pij and the previous probability vector P(n-1)×Pij (Xie and Pan, 2001). Based on this theory, the study obtained the prediction percentages of land use types of the coming years through the combination of the above two matrices, as shown in Table 5:

- Desert area will be increased year by year and the proportion will be increased from 66.78% in 2027 to 72.58% in 2063
- Heavy saline soil and vegetation will be increased after the increasing
- The proportion of city subdivision is limited but on the rise
- Both light saline soil and waters exhibit an increasing trend year by year

The above trends indicate that the management policy of Minqin Government obtains significant results. It make rational use of the land. In addition, there is a certain increase of urban land.

CONCLUSION

Based on the two sets of ETM+images, this study analyzed the 18 years' land use change of Minqin region in China and completed the following three main parts:

- Data processing and land use information extraction. The ETIM+images were supervised classified based on ENVI software and man-computer interactive interpretation. The land-use maps of Minqin region in China in 1991 and 2009 were generated. They provides data support for dynamic monitoring and analysis
- The land-use informations of Minqin in 1991 and 2009 were statistical analyzed to get the land use changes of each land type. They provide powerful support basis for the rational use of land and the land management measures implementation
- The land use status of Minqin in the future was predicted by the Markov model and the method could be used by other Arid and Semiarid Regions

The inadequacy of this study is that the information extraction mainly relies on the supervised classification and man-computer interactive interpretation. So it has low work efficiency. In the further researches, the multi-scale segmentation algorithm would be adopted for information extraction in order to improve efficiency and accuracy.

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