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LAND COVER CHANGES AND LANDSCAPE DYNAMICS ASSESSMENT IN LOWER REACHES OF TARIM RIVER IN CHINA

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ABSTRACT: The Tarim River Basin, located in the typical arid region, is one of the key regions of LUCC research in China and plays an important role in maintaining the sustainable development of the western China. In recent years, the ecological environment of the Tarim River Basin has degraded greatly. In the lower reaches, in particular, the riverbed has been dried up for more than 20 years, which accelerated the desertification and has been a great threat to people's lives. Taking the section of the Tarim River between Qiala Lake and Taitema Lake as a typical region, an investigation on land cover changes was carried out with the support of remote sensing information of 1988 and 2000 respectively. The changes of land cover in this region were obtained: 1) Cropland tended to increase. 2) Urban or Built-up Area in 2000 was 324.4ha more than that in 1988. 3) Waters expanded by 3476.51ha. 4) Woodland and Grassland decreased, while Barren Land increased by 3824.9ha. The total amount of land use/land cover change between 1988 and 2000 is small, which is only 0.355% of the total area. It shows that the developmental pace of the lower reaches of the Tarim River is relative slow. Based on these results, the authors assessed the landscape dynamics of this region and pointed out that the degree of desertification was strengthened and the landscape dominated by sand land was further characterized by salt desert.

KEY WORDS: Tarim River; LUCC; landscape evaluation; landscape ecological indices

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1 INTRODUCTION

As the longest inland river in China, the Tarim River is the "Mother River" of 8×10^6 people in the river basin. It runs across the biggest desert, Taklimakan Desert and Kuluke Desert (Fig.1), which are the typical arid regions in the western China (FAN, 1998; ZHU *et al.*, 2000). The Tarim River has once formed a natural screen protecting oases and important cities on the north edge of Tarim Basin. Since the 1950s, under the impact of human activities, especially the improper use of water, the ecological environment has degraded severely (FAN, 1991; JI *et al.*, 1998; WU, 1999; SONG *et al.*, 2000). Consequently, desertification has continuously expanded. What is more urgent is that the 320km-long riverbeds below Daxihaize Reservoir of the lower reaches have been dried up for more than 20 years (WANG *et al.*, 2000; WANG and YOU, 2000; WANG, 2002). The vegetation belt along No.218 national highway in the lower reaches, called "Green Corridor", is dying away. It was said that if this condition still continued it would become a gap of the fragile ecosphere, through which northwest wind would bring the expansion of desert area. Qiemo, Hotan and Ruoqiang counties would be buried by sand step by step, which would further threaten the ecological environment of Northwest China (WANG and FAN, 2000; FANG, 2001; TANG *et al.*, 2001). This tendency has become a limiting factor to the sustainable development of social economy of Tarim Basin (WANG and FAN, 1998; MA *et al.*, 2000). Since 2000, people have drawn water from Bosten Lake to the Tarim River four times, which has relieved the urgent situation in some extent. But it may be unable to resolve the ecological problems fundamentally because of the long-term arid climate and limited water

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amount. So the ecological environment of Tarim Basin is in urgent need to be improved effectively. Otherwise it will be another Lop Lake, which is also in Xinjiang and has become a fully desertified area from a lake in the 1980s (LI and ZHOU, 1998; FAN *et al.*, 2001; FANG, 2001). Therefore researches on changing processes of Tarim Basin become more and more important. This paper took the most fragile ecosystem of Tarim Basin, the lower reaches of the Tarim River, as a typical region and carried out researches on land cover changes and landscape dynamics evaluation. RS (Remote Sensing) and GIS (Geographic Information System) techniques were used in the study.

2 DATA ACQUISITION AND PROCESSING

2.1 Data Acquisition

The typical region selected is located in the lower reaches of the Tarim River in Xinjiang (Fig. 1). It covers an area of 1.33×10^6ha. In this research, two false color composite Landsat5 Thematic Mapper (TM) imageries of bands 4, 3, 2 taken in 1988 and 2000 were used for the recognition of synoptic data of the earth's surface in this region. Prior to analysis, both the TM images were rectified to Albers Equal-Area Conic Projection with a pixel resolution of 30m using Bilinear Interpolation provided by MGE /Image Analysis7.1.

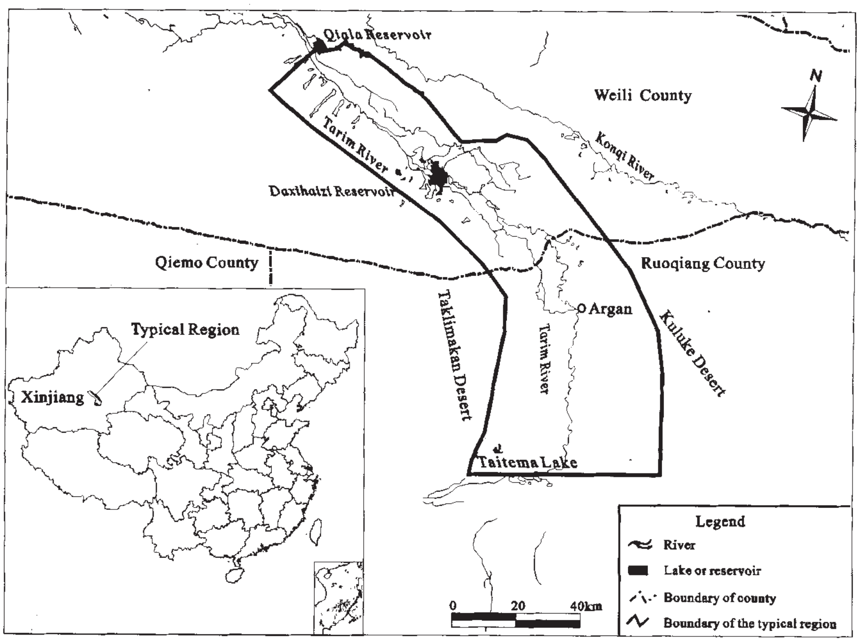

Fig. 1 Geographical location of typical region in Xinjiang

2.2 Classification System of Land Resources

A two-level land cover classification system was developed according to land use structure, also considering the accuracy that RS technique could reach. This system was compatible with what was currently used for environmental investigation of China (LIU *et al.*, 1996). It consists of 6 land use types at level Ⅰ, namely Cropland, Forestland, Grassland, Waters, Urban or Built-up Area and Barren Land. At level Ⅱ, from the viewpoint of land-use patterns, conditions and extent of difficulty to use, it was further divided into 25 categories.

2.3 Maps of Land Cover and Land Cover Changes

With the support of Arc/Info, we took those two TM imageries of this eco-region as background, and picked up objective land use types. As a result, two land use coverage in 1988 and 2000 were obtained. Then we overlaid the two coverage by Identity Command in Arc/Info to extract information of changes in land cover. In the end, the tendency of land use changes occurred in this period was obtained. Then starting from these changes, we carried out a comprehensive analysis of ecological conditions in this region.

3 ANALYSES OF LAND COVER CHANGES

3.1 General Pattern of Land Use in 2000

Overall, Barren Land was the dominant land use type in this region in 2000. The total area of Barren Land was 870 571.6ha, which occupied 65.57% of the whole region. Following Barren Land, Grassland was the next most abundant land use type. Its area was 359 018.2ha, which occupied 26.53%. Then were Forestland (4.33%), Cropland (2.86%), Waters (0.56%), and Urban or Built-up Area (0.15%). Dry farmland was the main component of cropland, whose area was 36 109.2ha. While the area of irrigated farmland was only 990.74ha. Forestland was dominated by shrub (*Tamarix* spp) and sparse woodland (*Populus suphratica*), which were 37 587.55ha and 9259.48ha individually. The lumber accumulation of Forestland in this region was low, 30.7m^3/ha. Grassland was constituted mainly by the grassland with low coverage, which did not suit the taste of livestock. Barren Land was mainly made up of sandy land, saline-alkali land and marshland. Among them, the sandy land area was 701 589.19ha, occupying 52.51% of the total area. The saline-alkali land area was 164 335.49ha, occupying 12.66% (Fig. 2).

3.2 Spatial and Temporal Land Cover Dynamics

A statistic table (Table 1) of land cover dynamics from 1988 to 2000 in this typical region were obtained through the contrast of land cover maps of 1988 and 2000. Such four characters marked the spatial and temporal land cover dynamics:

(1) Cropland tended to increase. The net increased area was 3650.93ha in this period, among which more than 90% came from the cultivation of grassland, and the others from the cultivation of barren land and forestland along riverside.

(2) Urban or Built-up Area in 2000 was 324.4ha more than that in 1988, which came from the occupation of cropland (289.2ha), grassland (17.6ha) and forestland (3.7ha). It showed the development of urbanization.

(3) Waters expanded by 3476.51ha. It was because of the high-flow year in 1999 and the extraction of water from Bosten Lake to Daxihaizi Reservoir in May, 2000, the water table increased. Even in the lower reaches of the Tarim River, which had been dried up for many years, Taitema Lake became to have water.

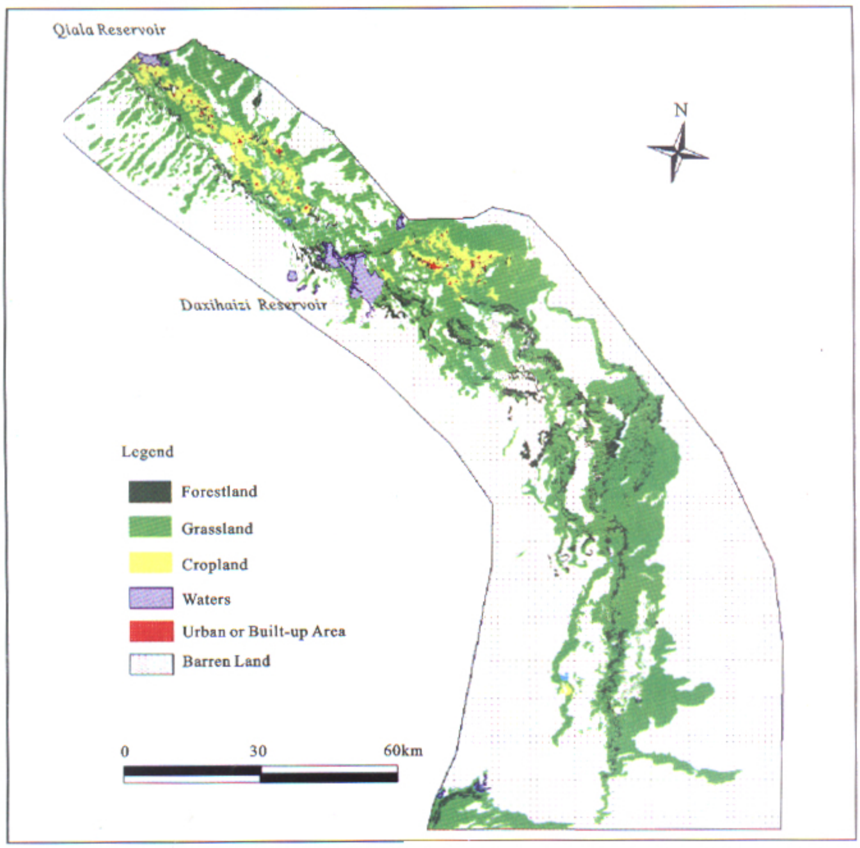

Fig. 2 Land cover of the typical region in 2000

(4) Forestland and Grassland decreased, while secondary soil salinization resulted from irrational use of water resources combined with desertification, salinification and alkalization had made Barren Land increase by 3824.89ha, which was 12.04% of the total changed area in this investigation region.

From the investigation result, we can see that in the period of 1988–2000, the changes of ecological environment can be summarized as "two enlarged and four reduced". That is, oases and sandy land increased at

Table 1 Transition matrix of land use/land cover in the lower reaches of the Tarim River (1988–2000) (ha)

1988	2000					
	Cropland	Forestland	Grassland	Waters	Urban or Built-up Area	Barren Land
Cropland	0.00	36.97	248.31	0.00	289.18	70.06
Forestland	82.56	0.00	3164.79	442.50	3.70	301.08
Grassland	3940.45	2111.51	0.00	1201.26	17.57	10967.81
Waters	0.00	0.00	246.75	0.00	0.00	569.62
Urban or Built-up Area	0.00	0.00	0.00	0.00	0.00	0.00
Barren Land	272.42	1245.05	3903.11	2649.11	13.97	0.00
Total	3650.93	–601.11	–10675.64	3476.51	324.42	3824.89

the same time, while other land cover types such as Forestland, grassland decreased. Overall, the total amount of land use/land cover change between 1988 and 2000 is small, which is only 0.355% of the total area. It shows that the development pace of the lower reaches of the Tarim River is relative slow. This situation is mainly caused by the bad natural ecological environment. The other reason is that the water scarcity resulted both from natural climate and from the unreasonable allocation of water resources among the upper, middle and lower reaches of the Tarim River has driven the ecological environment degradation gradually.

4 LANDSCAPE DYNAMICS EVALUATION

4.1 Indices of Landscape Evaluation

Landscape pattern is the spatial distribution of patches of different land cover type. Spatial features of landscape can be related with the temporal processes by analysis of spatial pattern to discover and describe the internal rules existing in land use clearly (LOEHLE and WEIN, 1994). Quantitative description of land use pattern is the foundation of analysis of land use structure, function and process. Landscape ecologists have given many indices about the quantitative description of landscape spatial pattern, such as landscape diversity, fragmentation, and fractal dimension of patches etc., which have put the foundation for the analysis of landscape spatial pattern (BAKER, 1989; XIAO, 1991; ALEXANDER *et al.*, 2002). These indices mentioned above were used in this paper (Table 2) to carry out quantitative analysis of the spatial pattern of landscape in the typical region in the lower reaches of the Tarim River.

Table 2 Models and ecological significances of landscape ecological indices

Index	Mathematic model	Ecological signifiance
Diversity (H)	$H = -\sum_{i=1}^{m}(P_i)\log_2(P_i)$ P_i is the percentage of the area of land use of type i to the total area of the typical region, m is the total number of the type of land use in the typical region	The equation shows the number of the type of landscape and the change of the percentage of each type to the total area. When the percentages of different types are equal the diversity is the highest.
Fragmentation (C)	$C = \sum_{i=1}^{m} n_i/A$ n_i is the number of land use patches of type i, A is the total area	Fragmentation can show the separation degree of land use. It is related with land resources protection closely.
Fractal dimension (D)	$D = 2\log(P/4)/\log(A)$ P is the perimeter of a patch; A is the area of the patch	It is often used to measure the complexity degree of the shape of patch.
Value of significance (D_0)	$D_0 = (R_d + R_f + L_p)$ R_f = (number of samples with patches/total number of samples)×100% R_d = (number of a type of patches/total number of patches)×100% L_p = (area of a type of patches/total area of patches)×100%	It shows the relative role and the dominant position of one type of patch in landscape.

4.2 Results of Landscape Evaluation

Combined the detailed land investigation data in the lower reaches of the Tarim River with the land use maps in 1988 and 2000, the authors calculated these above four indices (Table 3 and Table 4). From the results, we can draw such conclusions:

Table 3 The changes of landscape fragmentation in the lower reaches of the Tarim River

Section	1988	2000	Change
Upper section	0.181722	0.178623	–0.002099
Middle section	0.161093	0.167024	0.005931
Lower section	0.080439	0.080630	0.000191

Table 4 Landscape ecological indices in 1998 and 2000 in the lower reaches of the Tarim River

Land use	Diversity		Fractal dimension		Value of significance	
	1988	2000	1988	2000	1988	2000
Forestland			1.3385	1.3438	4.9254	5.1935
Shrub			1.3193	1.3271	4.7515	5.0525
Sparse forestland			1.3582	1.3614	10.1109	11.6152
Other forestland			1.2100	1.2117	0.5974	0.5980
High-covered grassland			1.2966	1.3055	2.7294	2.8610
Middle-covered grassland			1.2958	1.3238	5.5542	4.9125
Low-covered grassland			1.3298	1.3565	24.5937	24.1327
Canal			1.1292	1.1913	0.0853	0.3675
Lake	2.063*	2.085*	1.1959	0.0000	0.4009	0.0000
Reservoir, pond			1.1172	1.1786	0.2213	0.4836
Urban or built-up area			1.2653	1.2658	1.7568	1.8210
Sandy land			1.2704	1.5078	43.7785	44.3420
Saline-alkali land			1.3183	1.3538	23.9507	24.6888
Marsh land			1.2071	1.2508	0.6719	0.6561
Barren land			1.1064	1.1214	0.0869	0.1088
Paddy field			1.1323	1.2031	0.1640	0.6506
Dry land			1.2672	1.2724	3.3925	3.7141

* The data are for the whole typical region

When analyzing the landscape fragmentation, we divided the typical region into three parts. Those are Qiala Reservoir–Daxihaizi Reservoir, Daxihaizi Reservoir–Argan and Argan–Taitema Lake(Fig.1). From the landscape dynamics evaluation results we can see that the values of fragmentation of the three sections of the typical region in 1988 and 2000 were all below 0.2. In general, low fragmentation means the high landscape connectivity and strong resistance to environment changes. In this region, the low fragmentation resulted from the large area of continuous barren patches made the landscape be relative difficult to be changed and was always dominated by desertified land. Especially in the lower section (Argan–Taitema Lake) (Table 3), the fragmentation was only 0.080439 in 1988 and 0.08063 in 2000. There is nearly no change. In recent years, under the disturbance of human beings, such as man-made oases and newly built reservoirs etc., the fragmentation in the middle section (Daxihaizi Reservoir–Argan) increased. But in the upper section (Qiala Reservoir–Daxihaizi Reservoir), the fragmentation decreased because that sand land and saline-alkali land extended to connect each other due to land degradation.

From the fractal dimensions in 1988 and 2000, we can see that the fractal dimension of land use patches were large and that of sparse Forestland was always the largest, between 1.3582 –1.3614, which showed that the shape of land cover patches was relative simple. Linear patches, which were usually the distributing center of various species, were few. Therefore, the transmission efficiencies of energy flow, information flow and species flow were relative low.

In 1988, the landscape matrix was sandy land whose significance value was 43.7785. The subsequent three patches were low-covered grassland, saline-alkali land and sparse Forestland. In 2000, the landscape matrix was also sandy land, whose significance value increased to 44.342. The subsequent three patches became saline-alkali land, low-covered grassland and sparse Forestland. It shows that the desertification degree of landscape dominated by sandy land developed further by extending of salt desert.

The diversity index in the typical region was relative low both in 1988 and 2000. The landscape in this region is monotonous. Though the diversity index had increased to 2.085 in 2000 from 2.063 in 1998, there was no new component coming into existing in landscape. It was only the change of percentages of each component that caused the little increase of diversity in 2000.

From the results of landscape dynamics evaluation in the lower reaches of the Tarim River, we can see that the degree of desertification was strengthened. At the same time the increased significance value of saline-alkali land showed that in the typical region, the landscape dominated by sandy land was further characterized by salt desert.

5 CONCLUSIONS

(1) In 2000, the land use is absolutely dominated by Barren Land, occupying 65.57% of the whole region. The second dominant type is Grassland, 26.53%, and the others are Woodland, Cropland, Waters and Urban or Built-up Area in turns. Barren Land is mainly composed by sand land and saline-alkali land. Grassland is mainly in low-covered degree.

(2) Between 1988 and 2000, Cropland, Waters, Barren Land, Urban and Built-up Area had increased, while Forestland and Grassland had decreased. The total amount of land use/land cover change between 1988 and 2000 is small, which is only 0.355% of the total area. It shows that under the bad natural environment combined by people's unreasonable reallocation of water among the upper, middle and lower reaches of the Tarim River, the developmental pace of the lower reaches of the Tarim River is relative slow.

(3) From landscape dynamics evaluation in the lower reaches of the Tarim River between 1988 and 2000, we can see that the diversity index was relative low and had nearly no change among the 12 years. The landscape is monotonous. The fragmentation had decreased on the whole because of the connection of extending sand land and saline-alkali land due to land degradation. The shape of land cover patches was relative simple. Linear patches, which were usually the distributing center of various species, were few and the transmission efficiencies of energy flow, information flow and species flow were relative low. The increased significance value of saline-alkali land showed that in the typical region, degree of desertification was strengthened and the landscape dominated by sandy land was further characterized by salt desert.

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