RS-induced characteristics of land use change in Chongqing, China

Shao Jing’an

(*College of Geography Science*, *Chongqing Normal University*, *Chongqing* 400047, *China*)

Abstract: Used Landsat TM and interview data, this study reconstructed spatio-temporal trajectories of land use across Chongqing, southwestern China, for the period of 1986-2005. The results indicated that during 1986-1997, cropland used for built-up land, grassland and unused land reclaimed for cropland and woodland constituted for the three largest land uses, while 1997-2005, cropland returning into woodland, used for built-up land, of conversion to water body and unused land reclaimed for cropland and woodland were main land transformation types. Built-up land expanded widely at the expense of cropland, while the amount of grassland and unused land was reclaimed for cropland again. The rapid increase of woodland derived mainly from grassland and unused land exploitation and built-up land reclamation. Underlying causes resulted in the occurrence of previous changes included policy arrangement and original patterns of land resources. The former determines the basic orientations of land use at short-term scale, while the latter are crucial forces that figure the heterogeneity of regional land use. These trends were found to be indicative of increasing pressure on available land resources, leading to extensive significant for the development of land management policies, and for the monitoring of ecosystem status and trend.

Key words: land use change; temporal processes; spatial patterns; drivers

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0 Introduction

Currently, time series of remote sensing data with a high frequency of data acquisition have been directly linked to household survey data, opening new avenues to better link macro-economic transformations to land use changes[1,2]. Chongqing is the unique municipality of southwestern China. Over the course of the 20 years, it has experienced rapid socio-economic transformations, which present a range of threats to the continuing presence of what might be described as the traditional and historical mountain landscapes. At the same time, Chongqing, as ecological barrier of the upper reaches of the Yangtze River, has a very fragile ecological environment, thus any irrational human activities might be lead to irrecoverable ecological destruction. Moreover, in this region, the spatial-temporal dynamics of land use in the recent decade remain unknown. The main objective is to characterize quantitatively the spatial-temporal dynamics of land use trajectories in Chongqing, China.

1 Materials and methods

1.1 Study site

The study area is located in southwestern China (105°11'-110°11' E, 28°10'-32°13' N) (Fig.1), occupying 82268.65 km^2 area, with a population of 30.91 million. It attributes to subtropics humid monsoon. Annual mean temperature is 14−19℃. Annual rainfall is high and reliable, averaging 1000−1200 mm/a rainfall, with low inter-annual variation. The landscape is topographically heterogeneous, mainly consisting of mountain (over 1500 m elevation) and hill (300−400 m elevation). It has been a municipality under the direct jurisdiction of the State Council since 1997, and divided into the (better-developed) metropolitan area, the Yuxi (western Chongqing) Economic Corridor and the Three-Gorges Reservoir Eco-economic Zone (the Three-Gorges Eco-economic Zone). The metropolitan area covers 5473.00 km^2. The relief is characterized by small plains and low hills. The area per cropland is 0.052 hm^2. It is in a leading position in eco-social development in the western part of China and its fundamental conditions enable it to develop synchronically with the country’s eastern part. Its per capita GDP is 2.3-fold that of the Yuxi economic corridor and 3.6-fold that of the Three-Gorges eco-economic zone. The Yuxi economic corridor occupies 18861.09 km^2 area, with a topography of small plains, low hills and low mountains. The area per cropland is 0.107 hm^2. Its eco-social development is comparable to the average of the western part of the China. The Three-Gorges eco-economic zone possesses 57934.56 km^2 area. Its topography is featured by low hills and mountains. Average cropland area is 0.086 hm^2 per population. Its eco-social development is similar to the poverty-stricken counties of China’s West.

1.2 Data description

This paper focuses principally on the Economic Reform Era (1986-2005). The study period was divided into two study stages (1986-1997 and 1997-2005). TM (30 m ground resolution) imagery of three different years (1986, 1997 and

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Biography: Shao Jing’an, Ph.D. College of Geography Science, Chongqing Normal University, Chongqing 400047, China. Email: shaoja@lreis.ac.cn

2005) was taken from the national land use databases at a spatial scale of 1:100000. Visual interpretation and digitalization with technical support from Intergraph Modular GIS Environment software[3,4] were used to quantify land use dynamics during 19-year period. 1:100000 topographic and relief maps were selected from Chongqing Land Resource Bureau. Population records and socio-economic data were obtained from the Chongqing Statistical Yearbook. A series of preliminary interview questionnaires were conducted to elicit farmers' perceptions to land use change, associating with field survey.

The interpretation of TM images adopted the methods described by Liu et al.[4,5]. A hierarchical classification system was applied to the TM data[5]. To support image interpretation and the validation of land cover classification, this study has used a variety of data including DEM, roads and rivers. Field survey and random sample check were carried out to evaluate the classification accuracy. Interview data were summarized using 'ecological time lines'. The speed and regional difference of land use change was determined as described by Wang and Bao[6]. Regional orientation of land use change was evaluated by important value method described by Cai[7]. To in depth analyze the spatial change of land use, the conventional transition matrix was calculated through the formula by described by Braimoh[8].

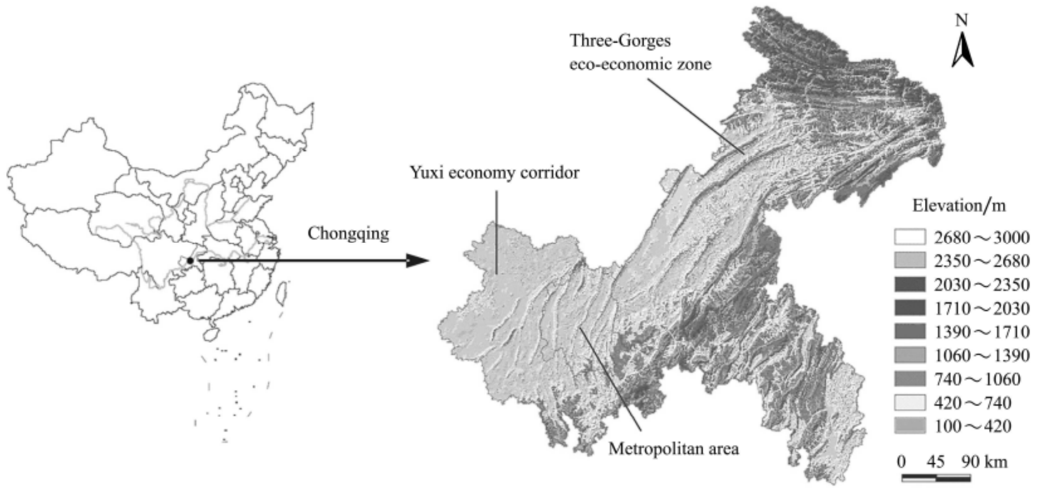

Fig.1　Digital elevation model in study area

2　Results and discussion

2.1　Key types of land transformation

For two stages, the patches possessing approximately 18.31% and 4.18% of total land area changed their land use patterns, respectively (Table 1). During 1986−1997, cropland used for built-up land, grassland and unused land reclaimed for cropland and woodland constituted for the three largest land uses, while 1997−2005, cropland returning into woodland, used for built-up land, of conversion to water body and unused land reclaimed for cropland and woodland were main land transformation types. For 1986−1997, unused land was reclaimed into woodland with the greatest area 452763.38 hm^2, and the sequence was the transformation of grassland to woodland with 375813.57 hm^2. Grassland and unused land were converted to cropland amounting to 301192.28 hm^2 and 159479.93 hm^2, respectively. Cropland occupied by built-up land was 104140.49 hm^2. During 1997−2005, the greatest land transformation area was cropland converted back into woodland with 243010.21 hm^2, and the cropland conversion to built-up land with 27,241.58 hm^2 was the second. Unused land cultivated for cropland, and cropland used for water body was amounting to 24551.31 hm^2 and 18592.35 hm^2, respectively.

Table 1　Main types of land use change from 1986 to 2005 in study area

Land use change	1986-1997		1997-2005	
	Area /hm^2	percent of total area/%	Area /hm^2	percent of total area/%
Cropland → woodland	4613.93	0.06	243010.21	2.95
Cropland → water body	10533.59	0.13	18592.35	0.23
Cropland → built-up land	104140.49	1.27	27241.58	0.33
Woodland → cropland	11591.25	0.14	/	/
Woodland → built-up land	5913.87	0.07	1336.59	0.02
Grassland → cropland	301192.28	3.66	/	/
Grassland → woodland	375813.57	4.57	/	/
Water body → cropland	38341.33	0.47	1767.96	0.02
Built-up land → woodland	36191.78	0.44	2409.66	0.03
Built-up land → water body	/	/	3162.95	0.04
Unused land → cropland	159479.93	1.94	24551.31	0.30
Unused land → woodland	452763.38	5.50	17032.92	0.21

2.2　Temporal processes of land transformation

Two-stage woodland, built-up land and unused land showed the same tendency, while cropland, grassland and water body took on the reverse directions (Table 2). Moreover, the speed of land transformation had greater differences, even for the same tendency. In the light of annual changing rate, 1986-1997, cropland increased by 1.27%, while paddy and dry farming land enhanced at

1.04% and 1.44%, respectively; 1997−2005, the decrease speed of dry farming land was 0.46% greater than that of cropland, and this number for paddy was 0.64% lower than that cropland. When compared with the changing rate of woodland, 1986−1997, shrub increased by 3.35% more rapidly than woodland, while forest presented the decrease current; 1997−2005, the augment speed of forest was 7.52% greater than that of woodland, but shrub showed the reduced stream. Similarly, 1986−1997, built-up land, urban and rural settlements and roads had the almost same increase behavior, but 1997−2005, the increase speed of roads was 0.92% greater than that of urban and rural settlements.

Table 2 Relative change rate of land use from 1986 to 2005 in study area %

Land use types	Metropolitan area		Yuxi economy corridor		Three-Gorges eco-economic zone		Chongqing	
	1986−1997	1997−2005	1986−1997	1997−2005	1986−1997	1997−2005	1986−1997	1997−2005
Cropland	1.40	1.45	1.31	0.20	0.79	1.35	+1.27	−0.76
Paddy	0.39	1.39	0.80	0.24	1.27	1.50	+1.04	−0.12
Dry farming land	2.12	1.48	1.86	0.24	0.57	1.24	+1.44	−1.21
Woodland	0.04	3.16	0.75	0.25	1.11	1.06	+3.72	+0.83
Forest	2.84	0.01	/	/	1.29	1.71	−0.18	+8.35
Shrub	0.56	4.26	3.29	0.21	0.91	1.16	+7.07	−2.88
Grassland	1.19	97.89	1.17	16.70	1.00	1.12	−7.40	+0.01
Water body	2.13	0.14	2.95	0.42	0.68	1.89	−1.01	+0.79
Built-up land	1.46	2.02	0.85	1.53	2.87	0.40	+1.79	+0.49
Urban and rural settlements	1.42	2.30	0.97	2.06	3.47	0.11	+1.81	+0.34
Roads	1.70	2.12	0.47	0.88	1.12	0.88	+1.72	+1.26
Unused land	1.62	1.23	1.56	1.13	0.81	0.98	−5.04	−0.72
Barren grassland	2.04	0.86	2.01	2.72	0.69	0.91	−4.20	−0.86
Bare soil and rock	1.32	1.87	1.26	/	0.90	1.12	−5.87	−0.52

A notable heterogeneity of land use transformation was detected among the three subareas. For cropland in 1st level classes, 1986-1997, the changing extent in Metropolitan area was the greatest (1.40%) in the three subareas, while in corresponding stage Metropolitan area had the smallest rate of paddy change (0.39%). For woodland change, 1986−1997, Three-Gorges eco-economic zone was the greatest (1.11%), while Metropolitan area was the smallest (0.04%). However, for 2nd level forest, in corresponding period, the greatest change even occurred in Metropolitan area (2.84%). During 1997−2005, the similar results also were observed. Urban and rural settlements in Metropolitan area and Yuxi economy corridor had 0.28% and 0.53% greater changing rate than built-up land, respectively. Road change in these places presented similar tendency, compared with built-up land. Bare soil and rock change in three subareas was the greater than that of unused land. Barren grassland change in Yuxi economy corridor was the greater than unused land, and this results in Metropolitan area and Three-Gorges eco-economic zone was the contrary.

2.3 Spatial patterns of land transformation

During 1986−1997, cropland used for built-upland and unused land reclaimed for wood distributed widely, their important value were 14.10% and 7.96% of the total, respectively (Table 3). During 1997−2005, cropland returning back to woodland had the widest distribution with 22.66% important value, and the sequence was the transformation of cropland to built-up land accounting for 6.26% important value. During 1986−1997, the expansion of built-up land at the expense of cropland was main land transformation types in three subareas, but Metropolitan area had the greatest important value (19.30%). Unused land exploited for woodland was observed primarily in three subareas as well, but the important value in Yuxi economy corridor was 7.69% and 1.36% greater than in Metropolitan area and Three-Gorges eco-economic zone, respectively. From 1997 to 2005, cropland returning back to woodland and built-up land expansion dominated primary land transformation types in three subareas, which the important value of built-up land expansion in Metropolitan area was 12.29% and 22.36% higher than in Yuxi economy corridor and Three-Gorges eco-economic zone, respectively.

Obviously, from 1986 to 1997, built-up land expanded widely at the expense of cropland, while amount of grassland and unused land was reclaimed for cropland. The rapid increase of woodland derived mainly from grassland and unused land exploitation. During 1997−2005, plenty of cropland was returned back to woodland. Moreover, the expansion of built-up land still occupied amount of cropland, but this occupation speed was slower than that of 1986−1997. Part cropland was converted to water body due to being inundated by Three-Gorgers Project. The minute analysis of three TM image overlay suggested that in two stages, cropland used for built-up land mainly distributed in the fringes of urban and rural settlements, and primarily showing cropland conversion to urban settlements (Fig.2). Grassland and unused land reclaimed for cropland (dry farming land) mostly happened in shallow hilly and plain area, while in low mountain area grassland and unused land conversion to woodland (shrub) were detected. During 1997−2005, cropland (dry farming land) returning to woodland (shrub) could be observed in low mountain area of Chongqing.

Table 3　Important value of main land use change from 1986 to 2005 in study area

Land use types	Metropolitan area		Yuxi economy corridor		Three-Gorges eco-economic zone		Chongqing	
	1986−1997	1997−-2005	1986−1997	1997−-2005	1986−1997	1997−-2005	1986−1997	1997−-2005
Cropland → woodland	0.40	32.86	1.02	20.82	0.13	30.87	0.39	22.66
Cropland → water body	0.25	1.42	0.12	/	1.16	2.36	0.82	1.55
Cropland → built-up land	19.30	26.32	10.49	14.03	10.87	3.96	14.10	6.26
Woodland → cropland	1.74	/	0.73	/	0.20	/	0.33	/
Woodland → built-up land	0.79	0.94	0.33	0.07	0.14	0.03	0.23	/
Grassland → cropland	0.25	/	3.73	/	10.28	/	5.15	/
Grassland → woodland	/	/	/	/	10.23	/	6.92	/
Water body → cropland	3.23	/	1.60	0.19	/	/	0.78	0.02
Built-up land → woodland	/	/	0.40	0.86	/	0.24	0.65	0.38
Built-up land → water body	/	/	/	/	/	0.70	/	0.42
Unused land → cropland	19.86	0.86	13.66	0.06	0.13	1.44	4.98	1.02
Unused land → woodland	3.05	1.43	10.74	0.44	9.38	0.74	7.96	0.67

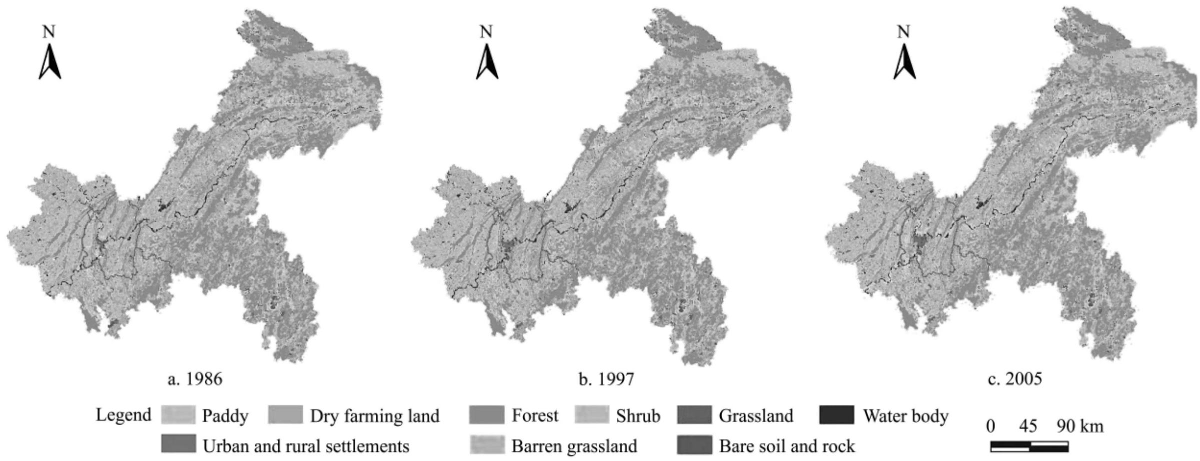

Fig.2　Nine-class land over map, derived from TM in 1986, 1997 and 2005 in study area

2.4　Drivers of land transformation

Arrangement of land policies, including household register system reform, croplands protect and cropland returning to woodland, determined the basic orientations of land use during 1986-2005. The increase of cropland area resulted from the implement of household responsibility system. Under this system, households had full rights in decision-making crop planting. To meet the population growth demand for foods and fibers, large sections of grassland and unused land were reclaimed for cropland. Moreover, the increase of cropland attributed to the policies of severe cropland protection, e.g., froze cropland for non-agricultural construction. Rapid expansion of urban and rural settlements was driven by the reform of household register system. Amount of rural population poured into urban. Various enclose land such developing area and estate involuntarily occurred, in virtue of the trade wind of urban development. Thus, the status of urban expansion was promoted further, and plenty of cropland was occupied. The augment of woodland resulted from the implementation of returning cropland to woodland policy, e.g., Grain-for-Green Project.

Original patterns of land resources, resulted from relief, location and natural disaster, figure various land use patterns. Metropolitan area had less grassland and unused land, due to the good relief conditions. Hence, the increase of cropland and woodland for two stages, resulted from reclamation of grassland and unused land, occurred mainly in Yuxi economy corridor and Three-Gorges eco-economic zone. At the same time, the reclamation of grassland and unused land focused mainly on 1986-1997. One, this result was that the amount of land exploitation neglecting protection was witnessed since the early 1980s. Another, the natural disasters frequently visited the study site since 1998, such as landslide, collapse, mud-rock flow and the large flooding of the Yangtze River. Moreover, regional heterogeneity of land transform presented fully the feature of location in study site. Initial area of urban land in Three-Gorges eco-economic zone was the lowest, thus small changing extent in land use can lead to relative greater changing rate. As shown in Table 3, 1986-1997, Three-Gorges eco-economic zone had the highest speed of built-up land expansion, especially urban and rural settlements.

3 Conclusions

Here, this paper, using an analysis of remotely sensed data gathered between 1986 and 2005, figured land use patterns in Congqing, China. During 1986-1997, in study site, cropland used for built-up land, grassland and unused land reclaimed for cropland and woodland constituted for the three largest land uses, while 1997-2005, cropland returning into woodland, used for built-up land, of conversion to water body and unused land reclaimed for cropland and woodland were main land transformation types. Obviously, cropland showed increase tendency during 1986-1997, while 1997-2005, the reverse results were detected, due to urban expansion and returning cropland into woodland. Presently, very limit unused land suitably reclaimed for cropland is undoubted[9]. Hence, research results had stronger policy implication for cropland protection, economic development and ecological conservation in southwestern China.

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重庆市土地利用变化特征的遥感分析

邵景安

（重庆师范大学地理科学学院，重庆 400047）

摘 要：使用 TM 影像和参与性农村评估获取的数据，研究了 1986-2005 年间重庆市土地利用变化的时空特征，结果表明：1986-1997 年间，耕地转为建设用地、草地和未利用地开垦为耕地或林地是重庆市 3 个最大的土地转换类型，而 1997-2005 年，这一转换则体现为耕地退为林地、建设占用耕地、耕地转换为水体和未利用地开垦为耕地或林地。建设用地的扩张以耕地的减少为代价，而同时又有大量的草地和未利用地开垦成耕地。林地的快速增加来源于草地和未利用地的开发和建设用地的复垦。同时，三峡工程的修建也使得沿江及其支流的部分耕地转换为水域。然而，驱动重庆土地利用变化的这一特征，其主要原因在于政策安排和土地利用覆盖的原始格局。前者决定短时期内重庆土地利用变化的基本方向，而后者则在大的环境背景下，决定重庆土地利用变化异质性的根本性力量。研究有助于理解后备资源短缺下的土地资源压力，对制定合适的土地管理时间策略，监测生态系统状况和态势具有重要意义。

关键词：土地利用变化；时间过程；空间格局；驱动力