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Original Research Paper

Urbanization Driving Forces of Unexploited Land Conversion in Ecologically Fragile Karst Areas of Southwest China: A Case Study of Guiyang City

Yan Liu*, Xianjin Huang*(**), Taiyang Zhong*(**) and Guangjie Luo*(***)
*School of Geographic and Oceanographic Sciences, Nanjing University, 163 Xianlin Street, Nanjing, Jiangsu Province 210023, China
**Land Development and Consolidation Technology Engineering Center of Jiangsu Province, Nanjing, Jiangsu Province 210023, China
***Institute of Agro-ecological and Rural Development, Guizhou Normal University, Guiyang, Guizhou Province, 550018, China (Corresponding author: Xianjin Huang)

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ABSTRACT

Urbanization is regarded to be one of the most important factors driving land use change. In this paper, through an integrated technique of RS, GIS and GPS, unexploited land conversion has been unveiled from 1996-2010 in Guiyang and further examination has been made on the impact of urbanization on unexploited land change. And based on the adjustment of Markov process, land use transition probability and CLUE-S parameters, many scenarios of unexploited land changes in the study area have been simulated. It is found that: (1) the unexploited land in Guiyang has experienced complex changes due to the rapid social and economic change since 1996. It showed a declining trend generally and was reduced from 74.33 km^2 in 1996 to 65.72 km^2 in 2010, a reduction of 8.61km^2 in 14 years. It has a close relationship with the rapid development of urbanization. (2) The urbanization comprehensive parameter (k) showed growth from 2.91% to 4.78% after urbanization development indicators were standardized during 1996-2010. (3) Regression analysis was used to unveil the relationship between urbanization and unexploited land. There was a significant correlation between them, which proved that the urbanization is one of the dominant factors to lead to exploited land change. (4) The unexploited land will show a significant decreasing trend in the coming 20 years, the conversion-out area will be larger than the conversion-in area in three scenarios and the gap will be widened gradually year by year. During multi-scenario simulations, unexploited land area decrease in ecological protection scenario is most prominent, the proportion of unexploited land converted to construction land in economic development scenario is the largest, and the area of grass land becoming unexploited land in unchanging trend scenario is the largest.

INTRODUCTION

China has extremely scarce land resources. It has experienced fast economic growth since 1978 (Gao et al. 1999). The accelerating urbanization process seems to be an important resource as it makes a great contribution to the regional development (Dinetti et al. 1996, EEA 2006, Jo 2002, Kong & Nakagoshi 2006, Kowarik 2011, Ho 2001). However, as a result, a large area of agricultural land has been converted into non-agricultural land and this makes agricultural land sparse (Akbari et al. 2003, Brabec & Smith 2002, Carsjens et al. 2002, Chen et al. 2009). Furthermore, population increase is still one of the reasons for land (especially the cultivated land) decrease. A population needs a number of immediate life sustaining needs such as food, fibre and residence space (Engelman & LeRoy 1995, Uusivuori et al. 2002, Feng et al. 2005). However, due to the finite amount of available land, fast economic development and population growth lead to deforestation, loss of cultivated land and biodiversity (Hobbs et al. 1991), and a reduction of environmental services (Lambin 1999, Xiao et al. 2013).

Differences in unexploited lands are significant in geographical distribution, as more than 60% of the unexploited land is distributed in western areas where water sources are less and the environment is more vulnerable. Ecosystems in mountainous karst areas are usually extremely fragile with low environmental capacity, high sensitivity to external interruption and poor self recovery capability (Yang 1990). Southwest China is one of the largest karst areas in the world, and is home to about 100 million people. Under the pressure of population and economic development, extensive land use intensity is high, which results in serious land degradation and even "rocky desertification", land degradation marked by soil erosion, which is the main environmental degradation problem in the southwest karst areas (Cai 1990, Cai 2001, Huang & Cai 2009, Wan 2003, Xu & Peng 2008). These problems of land use in karst areas have received increasing attention from the Chinese science community (Lan

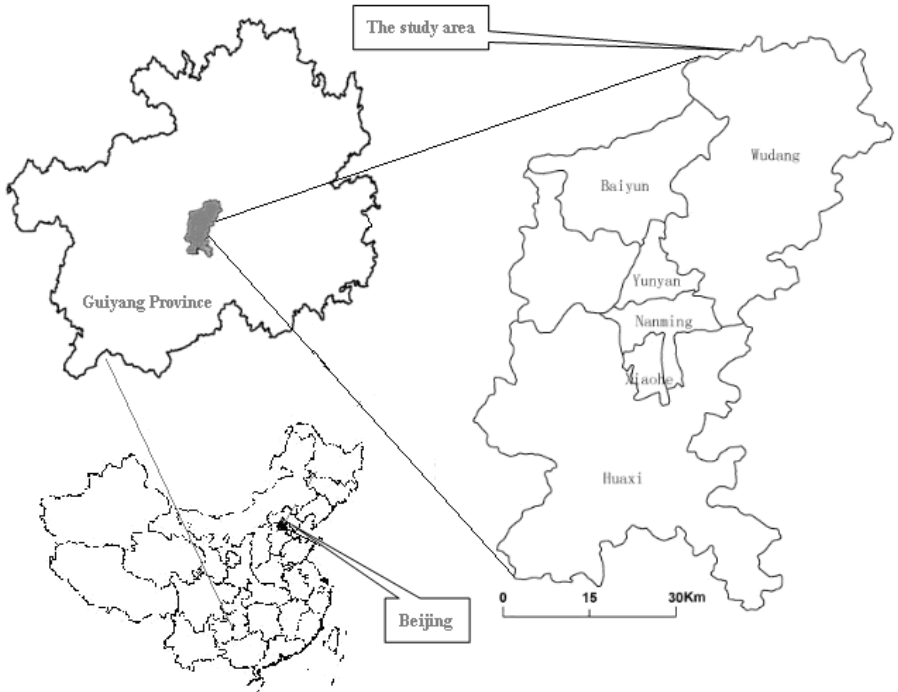

Fig. 1: Location of the study area.

et al. 2001, Peng & Yang 2001, Su 2002, Xiong et al. 2002, Yao et al. 2001). Studies have sharpened our understanding of the land use change process, the present state, driving forces and influencing factors (Peng et al. 2011).

Urbanization is regarded to be one of the most important factors driving land use change. According to the published literature, the relativity analysis of urbanization and cultivated land area change is more. Considering the importance of unexploited land development on both ecological and environmental situations, the existing study is very limited, and more efforts are needed to address the effect of urbanization on exploited land change. In ecologically fragile karst areas, this kind of empirical research is especially important. With Guiyang city as a case study, the authors here attempt to address (1) how unexploited land has changed in a typical karst area of southwest China from 1996 to 2010, and (2) to determine the effect of urbanization on converted unexploited land in the study area.

STUDY AREA

The study area includes Guiyang city, Guizhou Province, and includes six districts (Fig. 1), 54 townships, 32 sub-district offices and 131 village committees. The total area is 1510.12km^2 and the total population is 2.1408 million. It is located in the Fidel circulation cell which is controlled by westerlies all the year round. It has a mild, humid subtropical climate. The average annual temperature is 15.3°C, the annual average relative humidity is 78%, the average annual rainfall is 1129.5 mm, the average annual number of cloudy days is 235.1, and the average annual number of sunshine hours is 1148.3. The highest altitude is 1762m, the lowest altitude is 506m, the average altitude of the city center is 1000m, and the altitude difference is up to 1256m. 85% of the study area is covered by karst landform, and there are eight soil types: yellow soil, yellow-brown soil, limestone soil, purple soil, moisture soil, swamp soil, paddy soil and meadow soil, with yellow soil, limestone soil and paddy soil being the most widely distributed. Landforms in Guiyang city are mainly mountains and hills, it is a typical development area of karst, rocky desertification and potential rocky desertification phenomenon is prominent, and the foundation of ecological environment is poor. A long history of cultivation on steep slopes, excessive harvesting, deforestation, mountain deforestation for industry and mining and waste dumping phenomenon of a large number of earthwork and industry and mining arisings etc. resulted in frequent geological disasters, rapid soil degradation and serious ecological system destruction in Guiyang city.

MATERIALS AND METHODS

Land use classification: Land covers were classified in accordance with the classification system put forward by the Resource and Environment Information Center of the Chinese Academy of Sciences. Combined with land use characteristics of the study area and the interpretation accuracy of remote-sensing images, land use classification adopts Level

1 classification, by which the land use types can be classified into six types: arable land, construction land, forest land, grass land, water land and unexploited land. To better analyse the conversion between arid land and unexploited land in the study area, the arable land is divided into arid land and paddy land. GIS software ARCPINFO was used to generate vector data file, then a geographic information base was established, and ERDAS 8.5 was used to complete data file conversion. The ArcGIS 9.0 platform was used to perform map algebraic operation on land use maps of different periods to get land use change data for 1996, 2000, 2006 and 2010. A remote-sensing interpretation mark was established with weave band 432 false colour composite images. Classified templates of remote-sensing images were established in different time intervals with reference to Guizhou land use data in 1996 and 2000, and the precision of templates was evaluated with error matrix to ensure the error matrix value between different types of classified templates was larger than 85%. Land use information for TM images was collected by maximum likelihood classification method with reference to topographic map, land use map and other supporting information, and finally the precision of the classification results was evaluated. Classification results evaluation mainly relied on the land use maps of Guiyang in each period; with the combination of field survey data and visual method, the precision of the classification results of each time phase were tested, and then the result was tested with kappa coefficient. Its kappa coefficients in 1996, 2000, 2006 and 2010 were 0.83, 0.84, 0.84 and 0.81 respectively, which are all up to the requirement of minimum allowable discriminant accuracy at 0.7.

Urbanization comprehensive parameters: Urbanization development indicators including demographic, social and economic data for Guiyang were obtained from the following reports: Statistical Yearbooks of Guizhou Province, 1997-2011; Statistical Yearbooks of Guiyang City, 2003-2011; the Statistical Bulletin of the National Economic and Social Development of Guiyang City, 2000-2011. We established a comprehensive urbanization parameter, reflecting the environmental effect of land-use changes from urbanization (Li et al. 2004, Anwaer et al. 2009). Urbanization is affected by many factors such as urbanization (Y_1), economic level (Y_2), residents' living standards (Y_3), industrial structure (Y_4) and eco-environment (Y_5). These factors were selected as they are representative and easily quantified to reflect the development of urbanization. The urbanization level was defined and calculated as urban population divided by the total population; the economic level was per capita GDP; the residents' living standard was the disposable income of urban residents; industrial structure was the second and third industrial gross domestic product divided by regional GDP; the eco-environment was the green belt area per capita. Urbanization indicators were standardized by the maximum standardization method based on the Data Processing System (DPS) 14.10. The formula is:

$$X'_i = X_i / \max(X_i) \qquad ...(1)$$

$$X' = \sum X'_i \qquad ...(2)$$

Where, X_i represents the original value of a certain year i; $\max(X_i)$ is the maximum value between 1996 and 2010; X'_i is the standardization value of the index, i = 1, 2, ..., 5.

The urbanization comprehensive parameters $k = Y'$, k is calculated using the statistical data from the study area and eqs. (1) and (2).

Unexploited land prediction based on Markov model: Markov chain is a special process of movement with "ineffectiveness". It assumes that the state of a dynamic system at the time T+1 is related to that at T while having nothing to do with that before T. The transfer of development states of many things in the natural world has ineffectiveness; therefore, Markov chain model has been widely used in natural science research (Wang et al. 2004). Research showed that Markov model was more suitable for spatial data analysis; it can not only explore the change in quantity of land use types, but also can reason out spatial transfer characteristics of land use change. Markov model chain first divides the dynamic system of all studies into n possible states: $E_1 E_2 ... E_n$. Then calculates the state transition probability of mutual transformation between all states, and establishes a state transition probability matrix according to state transition probability:

$$p_{ij} = \begin{bmatrix} p_{11} & p_{12} & p_{13} \cdots & p_{1n} \\ p_{21} & p_{22} & p_{23} \cdots & p_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ p_{n1} & p_{n2} & p_{n3} \cdots & p_{nn} \end{bmatrix} \qquad ...(3)$$

Where, P_{ij} is the state transition probability from state E_i to state E_j; if an event is currently at state, then it may transfer from state to any one of the states at the next moment. So, meets the conditions:

$$\begin{cases} 0 \le p_{ij} \le (i, j = 1, 2, ..., n) \\ \sum_{j=1}^{n} p_{ij} = 1 (i = 1, 2, ..., n) \end{cases} \qquad ...(4)$$

Unexploited land simulation based on CLUE-S model: Conversion of land use and its effects model, or CLUE model, was developed by a "land use conversion and affection" research team of Netherland Wageningen University

(Veldkamp & Fresco1999a,1999b, Schulp et al. 2008), and was applied to the research on land use change trend simulation and policy (Hellmann 2011). The model is capable of simulating space-time dynamic changes of regional land use.

In this paper, Guiyang city is selected as the study area. The land use type area of four periods from 1996 to 2010 is known and the future land use demand is acquired by Markov model method to analyse the unexploited land. The stability of land used type conversion is usually represented by a value between 0 and 1, and the larger the parameter value is, the higher the stability of corresponding land use is. The setting of the stability parameter relies on the understanding of land use conversion in the study area and previous experience and knowledge. With the combination of the actual transition of all land use types in the study area from 1996 to 2010, the final ELAS parameters are respectively set as shown in Table 1. Land use type conversion matrix defines whether land use types can be transformed between each other by setting a matrix of conversion among all land use types. According to the historical dynamic and field survey of land use change in the study area, it is set that all land uses types can be transformed between each other.

Scenario design: In this text, three unexploited land change scenarios, namely business as usual scenario, ecological protection scenario and economic development scenario, are constructed by combining the predicted results of Markov model and modifying Markov process transition probability and input parameters of CLUE-S parameters. It also predicts the land use changes from 2010 to 2030.

Business as usual scenario: According to relevant policies and systems of unexploited land and land use transition probability matrix from 1996 to 2010 in the study area as well as the percentage of each land use type in area in 2010, we have predicted the land use change situation from 2010 to 2030 in the study area with Markov model.

Ecological protection scenario: The basis of the prediction: the first is the Twelfth Five-year Plan of West Region Development issued by National Development and Reform Commission confirming that Guizhou is a karst rocky desertification prevention area; to the plan requires expanding the scale of pilot area for comprehensive desertification treatment, and strengthening desertification treatment by enhancing forest and grass protection and construction, developing and utilizing reasonably grass land resources, and other measures. The second is in Special Planning for the Development and Utilization of Inferior Farmland in Guian New District formulated by Provincial Land Survey and Planning Institute under the entrustment of Guiyang Bureau of Land and Resources, which outlines a plan to increase new construction land by 1520 hectares within low-slope hilly region in 2013.

Table 1: ELAS parameters of each land use type under different scenarios.

Land use type	Business as usual scenario (UTS)	Ecological protection scenario (EPS)	Economic development scenario (EDS)
UL	0.60	0.50	0.40
PL	0.50	0.60	0.40
AL	0.86	0.90	0.80
CL	1.00	1.00	1.00
FL	0.80	0.90	0.80
WA	0.98	1.00	0.98
GL	0.70	0.80	0.60

Economic development prospect: The prediction is made on the basis of: Several suggestions of the State Council on Further Promoting the Economic and Social Development in Guizhou in a Better and Faster Way (G.F. [2012] No. 2 Document) which explicitly confirms the building of Guian New District into an inland development-type economic demonstration area, and encourages advanced trial in the fields such as land, investment, technological innovation, etc., which have pushed the conversion of unexploited land to industrial land to some extent. Overall Planning of Eco-civilized City for Guiyang 2007-2020 points out that by 2020 the urbanization level will reach 80% with an annual average increase of about 1%; GDP exceeds 300 billion Yuan with an annual average increase of about 11%; and GDP per capita is more than 8500. Thus, the unexploited land conversion of the study area from 2010 to 2030 can be predicted.

RESULTS

Unexploited land and other type lands change: The study results indicated that land use in Guiyang has changed significantly since 1996. Table 2 demonstrates the area and percentage patterns of different land cover categories in 1996, 2000, 2006 and 2010 as well as the changes in those time periods. The data show that the land use type in the study area is mainly arable land, forest land and construction land, with more than 80% of the total area of the study region in these four periods. Of those three land use types, arable land took up 36.94%, 32.00%, 25.51% and 20.42% of the total in 1996, 2000, 2006 and 2010 respectively. At the lower end, water land occupied only a small area, taking up 1.00%, 0.89%, 0.89% and 0.86% of the total area respectively in these four periods.

In the 14 years covered by the data, the land use in the study area changed significantly (Table 3). From 1996 to 2010, construction land and forest land showed an increasing trend, and other unexploited land, arable land, water land and grass land showed a declining trend. Among the later,

Table 2: Area and percent of different land-use types in the study area from 1996 to 2010 (Unit: km^2, %).

	1996		2000		2006		2010		1996-2000 change		2000-2006 change		2006-2010 change	
	Area	Percent	Area	Percent	Area	Percent	Area	Percent	Area	Percent	Area	Percent	Area	Percent
UL	74.33	4.95	60.40	4.03	67.03	4.47	65.72	4.38	-13.93	-0.93	6.63	0.44	-1.31	-0.09
AL	321.47	21.42	271.43	18.09	208.87	13.92	154.95	10.33	-50.04	-3.33	-62.56	-4.17	-53.92	-3.59
PL	232.85	15.52	208.67	13.91	173.98	11.59	151.33	10.09	-24.18	-1.61	-34.69	-2.31	-22.65	-1.51
CL	130.35	8.69	171.86	11.45	212.89	14.19	258.17	17.21	41.51	2.77	41.03	2.73	45.28	3.02
FL	550.09	36.67	607.21	40.47	655.29	43.67	703.94	46.91	57.12	3.81	48.08	3.20	4.65	3.24
WA	14.97	1.00	13.41	0.89	13.29	0.89	12.91	0.86	-1.56	-0.11	-0.12	-0.01	-0.38	-0.03
GL	176.43	11.76	167.51	11.16	169.14	11.27	153.47	10.23	-8.92	-0.59	1.63	0.11	-15.67	-1.04

UL - Unexploited land; AL - Arid land; PL - Paddy land; FL - Forest land; GL - Grass land; WA - Water land; CL - Construction land

Table 3: The area of unexploited land change from 1996 to 2010 (Unit: km^2, %).

	1996-2000			2000-2006			2006-2010			1996-2010	
	COT	NG	Conv. Rate	COT	NG	Conv. Rate	COT	NG	Conv. Rate	COT	NG
UL	34.11	22.21	-0.0468	30.35	37.09	0.0181	32.76	31.37	-0.0049	38.33	30.22
AL	134.82	86.51	-0.0389	118.74	43.26	-0.0384	97.83	43.79	-0.0645	194.81	35.21
PL	12.55	0.68	-0.2596	23.55	0.00	-0.0277	22.65	0.00	-0.0325	69.41	0.00
CL	0.00	40.97	0.0260	0.00	43.34	0.0132	0.00	45.28	0.0018	0.00	127.27
FL	67.49	121.19	-0.0126	16.45	73.31	0.0016	18.40	67.05	-0.0232	67.48	217.92
WA	0.68	0.00	0.0796	0.33	0.00	0.0597	0.18	0.00	0.0523	0.54	0.00
GL	88.37	52.76	-0.0261	46.62	39.04	-0.0015	45.75	30.08	-0.0071	67.48	44.55

UL - Unexploited land; AL - Arid land; PL - Paddy land; FL - Forest land; GL - Grass land; WA - Water land; CL - Construction land; COT - Converted to other types; NG - Newly generated; Conv. Rate - Conversion rate

the conversion area of arable land is the largest at 194.81 km^2. The land use change situation is different, however, in different time periods. From 1996 to 2000, the unexploited land, arable land, water land and grassland were all declining, among which, arable land reduced by 74.22 km^2 (4.94%) which was the largest amount of decrease; forest land and construction land increased by 57.12 km^2 (3.81%) and 41.51 km^2 (2.77%) respectively. From 2000 to 2006, the unexploited land, construction land, forest land and grassland all increased. The increased rates of forest land and construction land were the highest at 48.08 km^2 (3.20%) and 41.03 km^2 (2.73%), arable land declined by 97.15 km^2 (6.48%). From 2006 to 2010, while construction land and forest land increased, unexploited land, arable land, water land and grass land all declined.

Urbanization: In 1996, the Guiyang population was approximately 3,102,600, including the non-agricultural population of 1,391,300, with an urbanization rate of 44.84%. In 2010, the population reached 4,324,600, with the non-agricultural population increasing to 2,946,300. Compared with 1996, the rate of urbanization increased by 23% (68.13%). The rate of urbanization in Guiyang showed a positive trend from 1996 onwards (Fig. 2a).

Urbanization is not only reflected in the rate of urbanization, but also in social, economic and environmental areas. The gross domestic product (GDP) of Guiyang rose from RMB 17.119 billion to RMB 112.182 billion during 1996-2010. The primary, secondary and tertiary industry's GDP showed stable rational development, with the proportion of secondary and tertiary industries increasing by 23%. Per capita GDP increased from RMB 5414 to RMB 23126 in the same period. Urban per capita disposable income also increased from RMB 4312 in 1996 to RMB 16597 in 2005. The urbanization comprehensive parameter (k) showed linear growth after urbanization development indicators were standardized during 1996-2010 (Figs. 2b-2f).

Table 4: Correlation between k and the unexploited land change.

Year	1996-2000	2000-2006	2006-2010
R	-0.966**	0.808*	-0.577*

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

Regression analysis of urbanization and unexploited land: Table 4 shows correlation coefficient of urbanization comprehensive parameter (k) and unexploited land area change of three stages (1996-2000, 2000-2006, 2006-2010), with k impact on unexploited land from 1996 to 2000 is the most

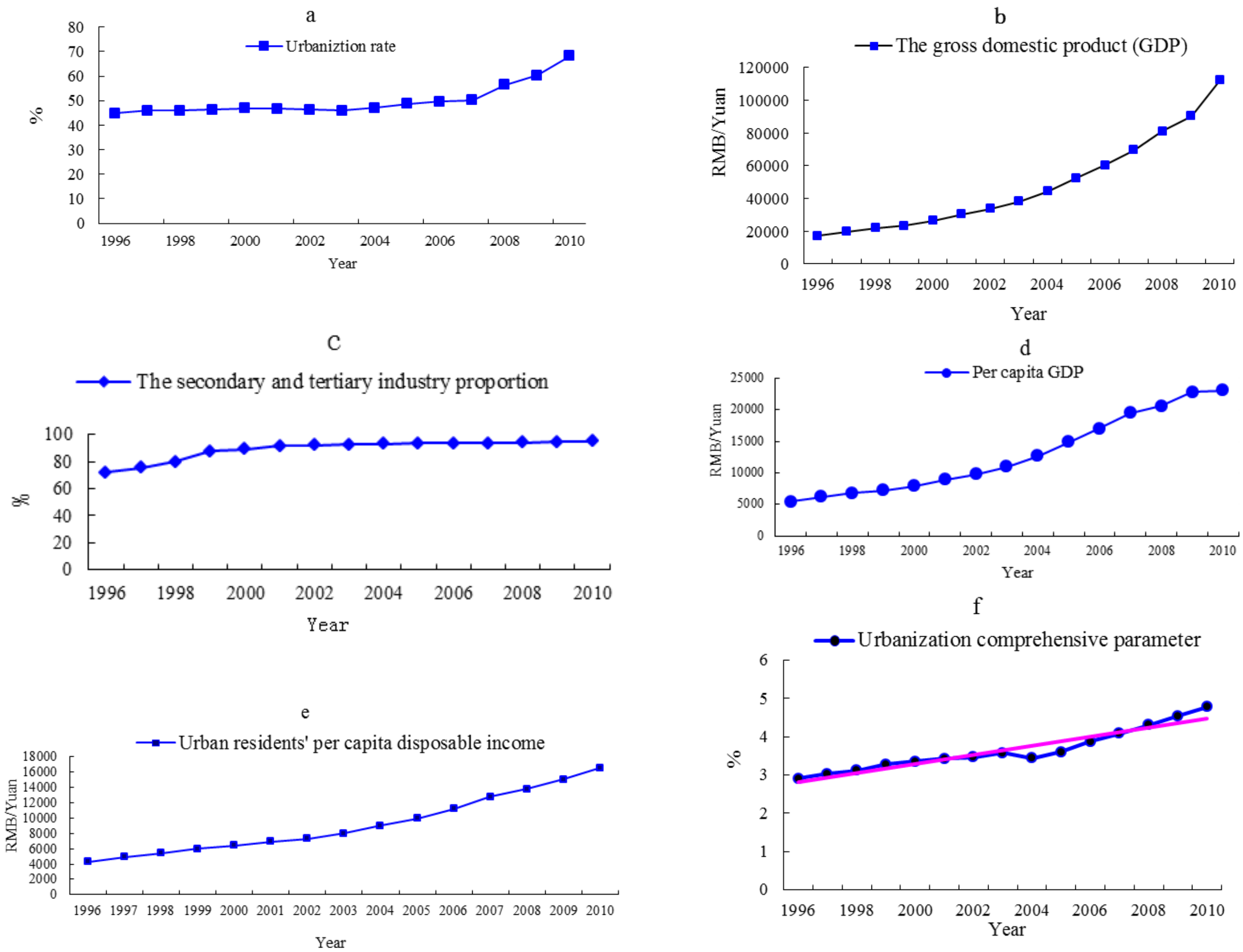

Fig. 2: Urbanization status of study area from 1996 to 2010. (a)-Urbanization rate; (b)-Gross domestic product (GDP); (c)-Proportion of secondary and tertiary industries' GDP; (d)-Per capita GDP; (e)-Urban residents' per capita disposable income; (f)-Urbanization comprehensive parameter (k).

significant (-0.966). By analysing the results, the urbanization process of three stages of unexploited change influence degree is different.

Through the period of 1996-2000: The regression analysis revealed influences from urbanization and policies in the period 1996-2000. The unexploited land conversion was mainly contributed to the change of urbanization.

$$Y = -27.612 + 153.446 \qquad (R^2 = 0.933)$$

Through significance test of α = 0.01, shows that urbanization is the main driving factor to lead to unexploited land change. Urbanization and unexploited land area showed a negative correlation relationship. Unexploited land will be reduced by 27.612km^2 when k increases by a point.

The period of 2000-2006: The relationship between the unexploited conversion and the urbanization comprehensive parameters during the period of 2000-2006 has shown a formula:

$$Y = 11.660 + 21.785 \qquad (R^2 = 0.654)$$

Through significance test of α = 0.05, shows that urbanization is the main driving factor to lead to unexploited land change. Urbanization and unexploited land area showed a positive correlation relationship. Unexploited land will increase by 11.660km^2 when k increases by a point.

The period of 2006-2010: The relationship between the unexploited conversion and the urbanization comprehensive parameters during the period of 2006-2010 has shown a formula:

$$Y = -6.910 + 66.221 \qquad (R^2 = 0.631)$$

Through significance test of α = 0.05, shows that urbanization is the main driving factor to lead to unexploited land change. Urbanization and unexploited land area showed a negative correlation relationship. Unexploited land will be reduced by 6.910km^2 when k increases by a point.

Table 5: Annual conversion rate of unexploited land during 2010-2030 (Unit: km^2, %).

	2010	2030	2010-2030 change	2010-2030 conversion rate
Business as usual scenario	65.72	44.23	-21.49	-0.0163
Ecological protection scenario	65.72	40.39	-25.33	-0.0193
Economic development scenario	65.72	43.34	-22.38	-0.0170

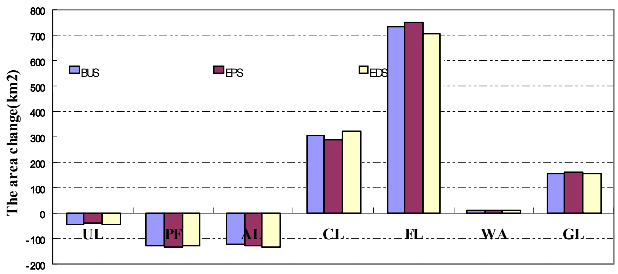

Fig. 3: The area change of different land use types in the study area from 2011 to 2030.

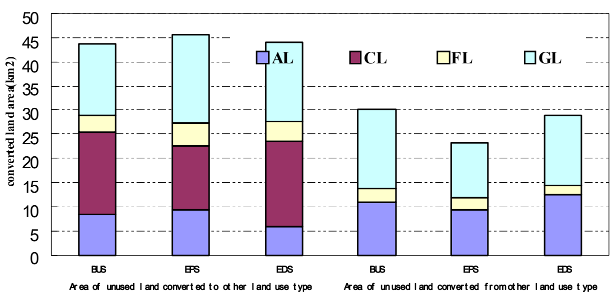

Fig. 4: The conversion of unexploited land from and to other land-use type during 2010-2030.

Prediction of unexploited land change: Changes in unexploited land and other land types from 2010 to 2030 are simulated under three scenarios in Fig. 3. The forest land, grass land and construction land areas in the study area will increase greatly; arid land, paddy field and unexploited land will continuously decline; and water land will change a little bit.

Unexploited land conversion is presented in Fig. 4. Under business as usual scenario (BUS), ecological protection scenario (EPS) and economic development scenario (EDS), the unexploited land conversion-out area is more than that of conversion-in from 2010 to 2030. These unexploited lands are mainly transformed to arid land, construction land, forest land and grass land. The conversion areas from unexploited land to construction land under BUS and EDS are larger, 17.05 km^2 and 17.78km^2 respectively, taking up 25.94% and 27.05% of the land use change under these two scenarios. In the economic development scenario, 16.58km^2 of the unexploited land is transformed into grass land, taking up 25.23% of the unexploited land area. The total conversion in area of the unexploited land under EPS is 23.25 km^2, smaller than that under BUS and EDS, which are respectively 30.14km^2 and 28.87 km^2.

However, in terms of absolute volume of unexploited land area, the prediction is that unexploited land will be declining under all the three situations. The conversion rate under EPS is the most prominent as the treatment on desertification is reinforced; under BUS and EDS, it is reduced, indicating that unexploited land in the study area is developed and utilized to different extents under the influence of relevant regulations and pushing of urban economic development. However, the changing range of the total area of the unexploited land is not in direct proportion with the degree of development, this is explained by continuous degradation and transformation of other land types. Based on this, it would seem that treatment of the ecological environment in these karst regions will be a long-term and complicated process (Fig. 4 and Table 5).

DISCUSSION

In this paper, we use the integrated technique of RS, GIS, and GPS to unveil unexploited land conversion from 1996-2010 in Guiyang, and further examined the impact of urbanization on unexploited land change. And based on the adjustment of Markov process land use transition probability and CLUE-S parameters, many scenarios of unexploited land changes in the study area have been simulated. It is found that the unexploited land in Guiyang has experienced complex changes due to the rapid social, economic and policy changes since 1996. The unexploited land in Guiyang showed a declining trend generally and was reduced from 74.33 km^2 in 1996 to 65.72 km^2 in 2010, a reduction of 8.61km^2 in 14 years.

Corresponding to the urbanization comprehensive parameters increase, mainly land types conversions revealed dissimilar trends from the period 1996-2000. The conversion rate of unexploited land was increased from -0.0468 to 0.0181. The conversion rate of grass land was increased from -0.0126 to 0.0016. However, the conversion rate of construction land and forest land was reduced. The construction land decelerate from 0.0796 to 0.0597. Forest land reduced from 0.026 to 0.0132. Paddy land and arid land basically remained unchanged during 2000-2006 (Table 3). The negative environmental impact, as the rapid urbanization, was visible at this period. It is thus clear that urbanization has produced significant influences on the conversion of unexploited land in ecologically fragile karst areas of southwest China. However, ecological environment construction is the priority in west region development, pressure and risk of further ecological degradation caused by various factors in karst area still continue to be a concern.

The rapid development of urbanization of Guiyang city is the main cause of unexploited land change. The negative correlation relationship during the period of 1996-2000 and 2006-2010, and the positive correlation relationship in 2000-2006 between urbanization and unexploited land have shown that the unexploited land reduced or increased to have a close relationship at different stages with the rapid development of urbanization. Unexploited land was used as a reserve for cultivated land resources for a long time and has the ecological function. Therefore, the rapid growth of the urban construction and economic development are important reasons to impact the food security and ecological environment etc. posing a series of questions about the sustainable development.

CONCLUSIONS

1. It is found that the unexploited land in Guiyang has experienced complex changes due to the rapid social, economic and policy changes since 1996. The unexploited land in Guiyang showed a declining trend generally and was reduced from 74.33 km^2 in 1996 to 65.72 km^2 in 2010, a reduction of 8.61km^2 in 14 years. It has a close relationship with the rapid development of urbanization.
2. The urbanization comprehensive parameter (k) showed growth from 2.91% to 4.78% after urbanization development indicators were standardized during 1996-2010.
3. In this paper, regression analysis was used to unveil the relationship between urbanization and unexploited land. There was a significant correlation between them, which proved that the urbanization is one of the dominant factors to lead to exploited land change.
4. The results of prediction of unexploited land change indicate unexploited land will be a declining trend under all three scenarios, and reduction of unexploited land under the ecological protection scenario is most prominent in 2010-2030. The conversion-out area is larger than conversion-in area under all scenarios; conversion into grass land under ecological protection scenario is larger; conversion into construction land under business as usual scenario and economic development scenario are significant. The conversion sources include arid land, grass land and forest land, and of these the proportion of grass land converted into unexploited land under an unchanging situation is higher.

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