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Tourism and Land Transformation: A Case Study of the Li River Basin, Guilin, China

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Abstract: Land-use change is intertwined with tourism because land is used as a resource for human activities. Land-use change also provides an opportunity to evaluate the status of the eco-environment. Understanding the relationship between tourism and land use change would help to predict the effect of tourism on land use and encourage sustainable tourism development. Using the Li River Basin as a case study, a hybrid approach using multilevel modeling and logistic regressions was employed to analyze the distribution of land-use-change between 1989 and 2010 to examine potential driving factors. Results reveal that rapid tourism development and construction expansion expose this area to risk of deforestation and forest degradation. Construction increased by 141% between 1989 and 2000 and by 195% between 2000 and 2010. The primary driving force for construction expansion shifted from population growth between 1989 and 2000 to investment growth after 2000. New construction primarily occurred on crop and woodlands areas, with shares of 81.25% and 6.38%, respectively, between 1989 and 2000, and with shares of 57.79% and 15.29%, respectively, between 2000 and 2010. Moreover, these drastic increases in construction also led to frequent transitions between croplands, woodlands, and grasslands. Traits including distances to urban areas and roads and scenic locations exerted significant effects on land-use change. Woodland regrowth in the areas that surround scenic locations consisted of fluctuating woodlands, whereas stable woodland regrowth was often absent in these areas. Likewise, permanent woodland clearing tended to be closed to near scenic locations. That is, construction at scenic locations negatively affected forest conservation in the Li River Basin.

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Abbreviations: GDP (Gross domestic product); TM (Thematic Mapper); DEM (Digital Elevation Model); ILCC (Inter-levels correlation coefficient); ROC (Receiver-operating characteristic curve); LUCC (Land use/cover change)

Introduction

Natural and anthropogenic causes drive land-use change. Over time, anthropogenic land-use changes have dramatically modified the surface of our planet and affected biophysical systems, resulting in: pollution, ecosystem degradation, water scarcity and decreased standards of living (DeFries and Eshleman 2004; Verburg et al. 2009; Khaledian et al. 2012). Thus, research has scrutinized land dynamics in terms of coupled human-environment systems (Lambin et al. 2001; Reynolds et al. 2007; Turner II and Robbins, 2008). Growth of the tourism sector can stimulate local economies and create jobs (World Tourism Organization 2012); however, the rapid growth of tourism simultaneously exposes local environments to increasing environmental pressures (Pickering and Hill 2007; Zhong et al. 2011). Thus, tourist regions represent typical cases from which to gain a local-scale understanding of the land-use changes caused by the tourism industry. Land is an important resource for hosting human activities, and land use is not only a consequence but also a driving factor of tourism development. Land use in tourist regions must manage trade-offs between resource consumption and ecosystem conservation. Understanding the effect of tourism on land-use changes and its feedback can help balance the demand between local development and environmental conservation to achieve sustainable tourism.

According to recent studies, the effect of tourism development on land-use change can be divided into five dimensions. (1) Constructions for tourism infrastructure often occur in forests, wetlands and croplands (Kuvan 2005; Zhao 2010; Kayhko et al. 2011). (2) The environmental changes resulting from tourism development have additional effects on land-use change (Gossling 2002a). For instance, filling seas to construct aquatic recreation facilities interferes with the erosion of shorelines and changes land area (Davenport and Davenport 2006). (3) The increasing land-use demands associated with tourism resource consumption leads to deforestation and the expansion of low-density construction in tourist regions (Wang and Liu 2009; Gaughan 2009). (4) Several types of artificial tourism projects (e.g., theme parks, ski resorts, hot springs, country clubs, and golf clubs) require large land areas while exposing local environments to potential eco-risks (Markwick 2000; Dong 2007). (5) Population growth, culture shock, and industrial transformation combined with tourism development can indirectly affect land-use change (Gossling 2001 2002b; Marin-Yaseli and Martinez 2003; Williams and Shaw 2009; Strickland-Munro et al. 2010). At a local level, tourism development must balance the land-use demand between tourism and other industrial sectors as well as between resource consumption of tourism and environment conservation (Petrov et al. 2009). At an individual level, tourism development must coordinate the interests of different stakeholders (e.g., citizens, farmers, the government, developers, tourists, and even local endangered species; Carte et al. 2010). To support insightful land management in tourist regions, suitable spatial and non-spatial information is required to balance human needs with ecosystem functions (DeFries et al. 2004). Many studies have discussed the economic benefits and environmental consequences associated with tourism development and have offered useful non-spatial information to elucidate the effect of tourism on local land dynamics. However, tourism development embodies significant spatial characteristics similar to land-use change. Thus, discussing the spatial relationships between land-use change and tourism development would help to deepen our understanding of land-use change within tourist regions.

Regression analysis is a useful tool for revealing the driving factors of land-use change. However, scale issues have shown that topographic, demographic, economic, and institutional data possess different levels of specificity that can hinder the use of this approach with regard to land-use change research and coupled human-environment systems. Several researchers have introduced multi-level statistics into the study of land-use change, including factors with different specificities in regression models (Hoshino 2001; Overmars and Verburg 2006). Multilevel statistics were created in the 1980s and are frequently used in sociology, education, and the medical sciences. This approach applies regression techniques to datasets with hierarchical structures by including independent variables at different levels (e.g., individual and group levels; Serneels et al. 2007). If one treats each land-use unit as an individual and the administrative unit to which it belongs as a group, then land-use change driving-factor datasets have hierarchical structures. Thus, the multilevel approach allows researchers to employ regression techniques to determine the socio-economic and eco-environmental factors that influence land dynamics.

Land-use types and patterns are more diverse and flexible in mountainous areas where the ecosystem tends to be more vulnerable. Likewise, mountainous areas contain numerous natural resources, including tourism resources. Vulnerable ecosystems and abundant resources requires mountainous areas to manage the trade-offs between development and conservation. The Li River Basin covers approximately 5306.06 km² of mostly hilly and Karst terrain. Mountains and hills predominate the upper reaches of the basin, whereas hilly and Karst terrain predominate the middle and lower reaches. Due to the intense human activities associated with tourist activities present at the middle and lower reaches, the upper reaches have been confronted with a severe ecosystem conservation situation. Land degradation, deforestation and reduced runoff threaten the sustainable development of this area. Therefore, this study uses the Li River Basin as a case study, employs a multilevel logistic regression model to analyze the spatial distribution characteristics of land-use change during the last two decades and examines the possible driving factors. Based on the results of this model, this paper explores the effect of tourism development on land-use patterns.

1 Study Area and Data

1.1 Study Area

The Li River Basin lies completely within Guilin City, which is in Guangxi Zhuang Autonomous Region, China. It is located between 110°7'42" ~ 110°42'50" E and 24°38'15" ~ 25°53'56" N (Figure 1). This basin is approximately 5306.06 km² in size, and the length of the Li River is 164 km. The upper reaches of the Li River stretch from the river's source to the downtown Guilin; landform is dominated by hills with fertile farmland. The middle reaches of the Li River (from downtown Guilin to Yangshuo County) and the lower reaches (from downtown Yangshuo County to the boundary with Pingle County) are Karst landforms with clusters of natural tourism resources. The Li River Basin has a semi-tropical monsoon climate with an annual precipitation that ranges from 1400 to 2000 mm. The mean annual temperature ranges from 17°C in the north to 20°C in the south, and there is ample synchronous sunshine and rainfall conducive to crop production. Moreover, deep alluvial and paddy soils are widely

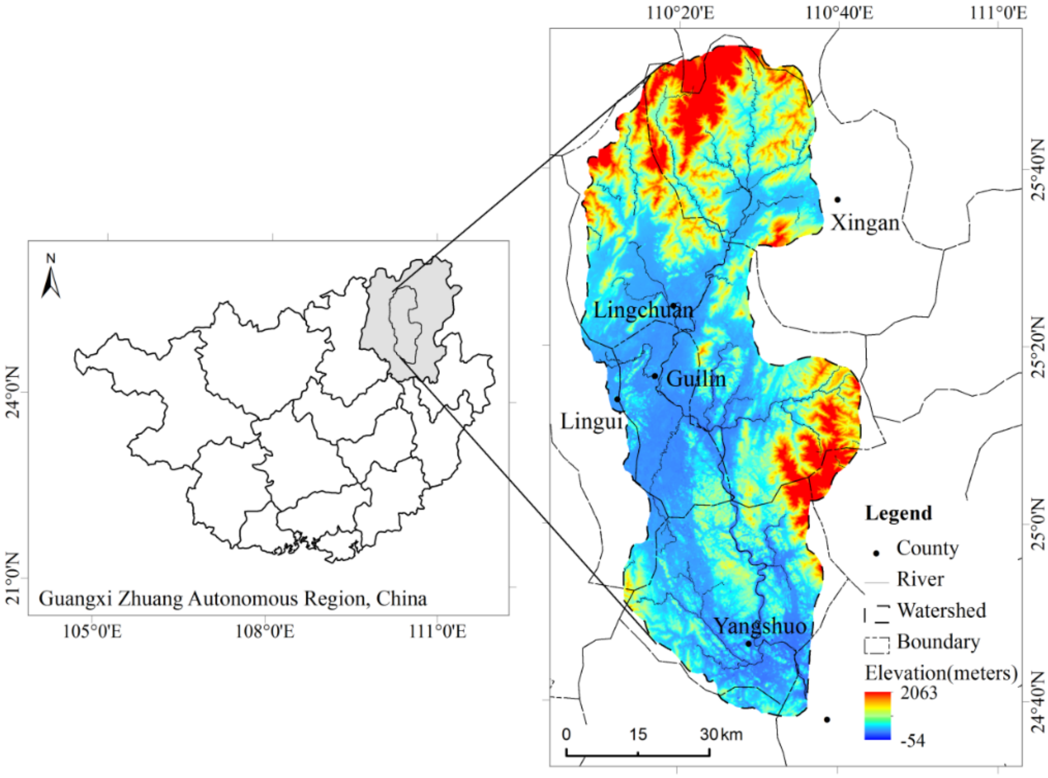

Figure 1 Study area location (Li River Basin, Guilin).

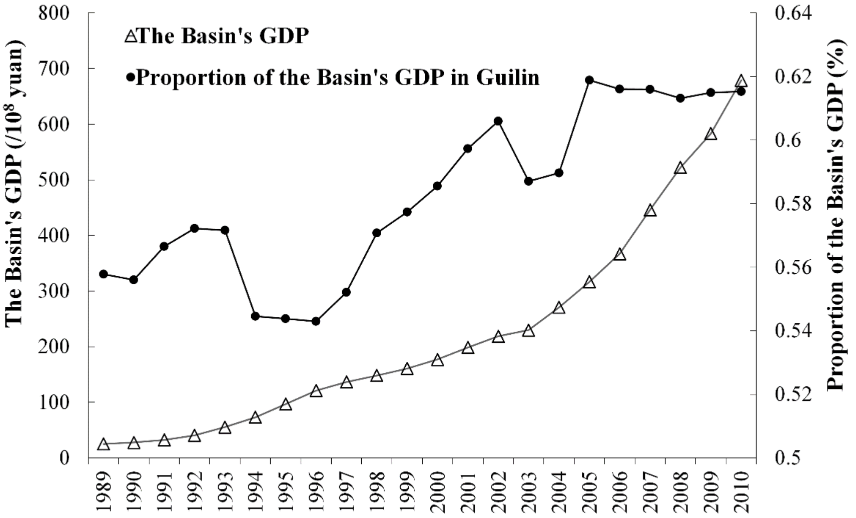

Figure 2 The GDP of the Li River Basin and its proportion of the total GDP of Guilin between 1989 and 2010.

distributed in the Li River Basin; thus, the favorable climate and soil conditions make the Li River Basin the most important base for plantations in Guilin. In addition, three nature reserves are located in its upper reaches: the Mountain Mao'er Nature Reserve, Qingshitan Nature Reserve and Mount Haiyang Nature Reserve.

The Li River is located in Guilin, which is the third largest city in the Guangxi Zhuang Autonomous Region and the focus of agriculture and tourism economic development. The Li River Basin covers the major urban area of Guilin and hosts most of the socio-economic activities of Guilin. In 2010, the population in the basin was 2,320,000. 44.66% of the population lived in the city, and the total non-agricultural population was 871,000 (70.82%). The proportion of the basin's gross domestic product (GDP) with respect to the whole of Guilin stood at 62% in 2010 (Figure 2). However, there were two marked drops in this proportion that were driven by different forces from 1994 to 1996 and from 2003 to 2004. The former reduction was primarily due to the spatial shift and restructuring of the industrial plants that accompanied the growth of the economic development zone. Industrial plants relocated outside the basin, which led to the steep reduction of the proportion of the basin's GDP. In contrast, the latter reduction was briefer and, to a large extent, resulted from the nationwide outbreak of Severe Acute Respiratory Syndrome (SARS) that affected tourism and the service sector. In general, the Li River Basin is the core local economic development area in Guilin.

The Li River Basin is a cluster of tourism resources and plays an important role in Guilin tourism development. Approximately 20 scenic locations ranked higher than the AAA-level are located within the basin. In 2010, the tourism income of the Li River Basin reached 1.59×10^{11} yuan (i.e. Chinese Yuan), representing 94.59% of tourism income in the whole city; tourism income increased drastically since 2000, with a growth rate of 13.9%. The number of tourists was approximately 20,000,000 in 2010. In 2009, the State Council of China officially designated Guilin as an experimental area for the integrated reform of tourism development. Changes in the institutional environment determined a new path for future development in the Li River Basin.

Due to its general status as an important base of plantations, a core area of economic growth, and a cluster of tourism development, the Li River Basin is a typical multi-functional landscape that must manage the trade-offs between human needs and eco-system functions because the local development could, in return, destroy the foundation for its progress, which is the eco-system.

1.2 Data

Three Landsat Thematic Mapper (TM) images from 1989, 2000, and 2010 were used to obtain land-use information. Using visual interpretation and other conventional image-processing methods, land use in the Li River Basin was divided into five types (Figure 3). Cross-validation was employed to test the precision of the land-classification results. The precision of the three land-use maps ranged from 0.80 to 0.85, and they meet the demand of land-detection research. The basic geographic data (at a 1:250,000 scale) that included administrative divisions, roads, rivers, other water bodies, and residential areas were obtained from the Chinese

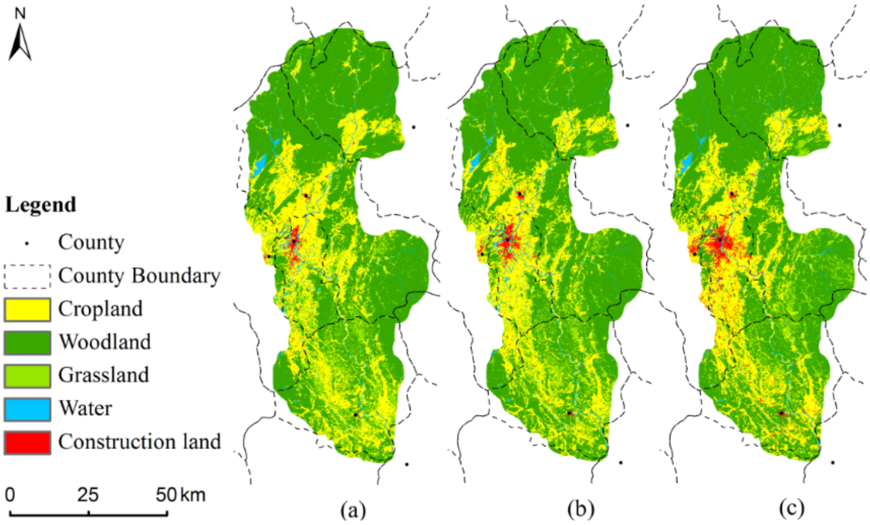

Figure 3 Land-use maps for (a) 1989, (b) 2000, and (c) 2010.

Research Academy of Environmental Sciences. A Digital Elevation Model (DEM) was obtained from the International Scientific Data Service Platform of China. Slope and elevation data were obtained from the DEM. The distribution of the scenic locations ranked higher than the AAA level was digitized from relative maps using ArcGIS Desktop. The socio-economic data collected from 1989 to 2010 were obtained from the Guilin Bureau of Statistics and the Annual Government Report. The geographic coordinate system in this paper is WGS_1984_Transverse_Mercator.

2 Methods

Regression is a useful technique for exploring the factors that influence land-use change. If the spatial variables describing land-use change are binary, then a binary logistic regression can be used to detect the spatial characteristics of land distribution and obtain potential land-use-change maps. The binary logistic regression model can be written as

$$\log(p/(1-p)) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n \qquad (1)$$

where, p is the probability of a particular land-use change, x represents the driving forces of land-use change, β_0 represents the intercept, and β_n represents the coefficient of each variable.

Land dynamics have socio-economic and eco-environmental attributes. Normally, socioeconomic information is evaluated at the administrative division level. Obtaining this information for each land unit is impossible for a local-level research. Thus, local-level research must consider socioeconomic and physical information using different specificities. If each land unit is treated as an individual within a group, then land units and administrative division form a hierarchical structure. Land units are able to denote differences in physical information, whereas administrative divisions can exhibit socioeconomic differences. Multilevel models are designed to handle cases with nested data that conventional logistic regression models are unable to consider (Zhang et al. 2003). Multilevel models do not simply introduce variables at different levels into the model; rather, they divide variables into different levels and include an error term at every level to examine the effect within and between groups (Overmars and Verberg 2006). In this paper, land-use (individual level) was nested within counties (group level). The null model (Formula 2) was constructed to examine the between-group effect; if this effect was significant, then the multilevel model was used to examine the potential factors of land-use change. Otherwise, a conventional logistic regression model was employed.

$$\log(p/(1-p)) = \gamma_{00} + u_{0j} \qquad (2)$$

In Formula 2, p represents the probability of land-use change, γ_{00} represents the general intercept, u_{0j} represents the group-dependent deviation, and j represents different counties.

The inter-levels correlation coefficient (ILCC) was calculated to obtain the between-group effect, which represents the higher level's proportion of the total variation. For a two-level model, the ILCC is expressed as follows:

$$\rho = \mathrm{Var}(u_{0j}) / (\mathrm{Var}(u_{0j}) + \pi^2/3) \qquad (3)$$

where $Var(u_{0j})$ denotes the variation in group-dependent deviation. The ILCC ranges from 0 to 1, and larger coefficients denote more significant between-group effects; in our case, these effects would suggest that differences between counties affect land-use change.

The multilevel logistic model was written as follows:

Level-1 (Land Unit):

$$\log(p/(1-p)) = \beta_{0j} + \beta_{1j}a_{1ij} + \cdots + \beta_{qj}a_{qij}$$

Level-2 (County):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}b_{1j} + \cdots + \gamma_{0r}b_{rj} + u_{0j}$$

$$\cdots$$

$$\beta_{qj} = \gamma_{q0} + \gamma_{q1}b_{1j} + \cdots + \gamma_{qr}b_{rj} + u_{qj} \qquad (4)$$

where p represents the probability of land-use change; i and j denote the number of land units and counties, respectively; a represents the Level-1 factors; q represents the total number of Level-1 factors; b represents the Level-2 factors; r represents the number of Level-2 factors, β_{0j} represents the Level-2 intercepts; γ_{00} represents the general intercept; β_{qj} and γ_{qr} denote the coefficients in Level-1 and Level-2, respectively; and u represents the error term.

The multilevel logistic regression model in this study was performed using HLM 6.02. Using stratified sampling, 2000 random points that denoted the changing areas of particular land-use types and 2000 random points that denoted unchanged areas were generated. These points were used to map the influencing factor data. When a particular land-use change occurred, the dependent variable was set to 1; 0 represents no change. Based on the actual conditions of the Li River Basin, 17 criteria were used to assess its topography, accessibility, and socioeconomic conditions (Figure 4, Table 1). To test the prediction ability and accuracy of our model, a receiver-operating characteristic (ROC) curve was employed, and the area below the ROC curve was denoted as the ROC-value. This value ranges from 0.5 to 1; ROC-

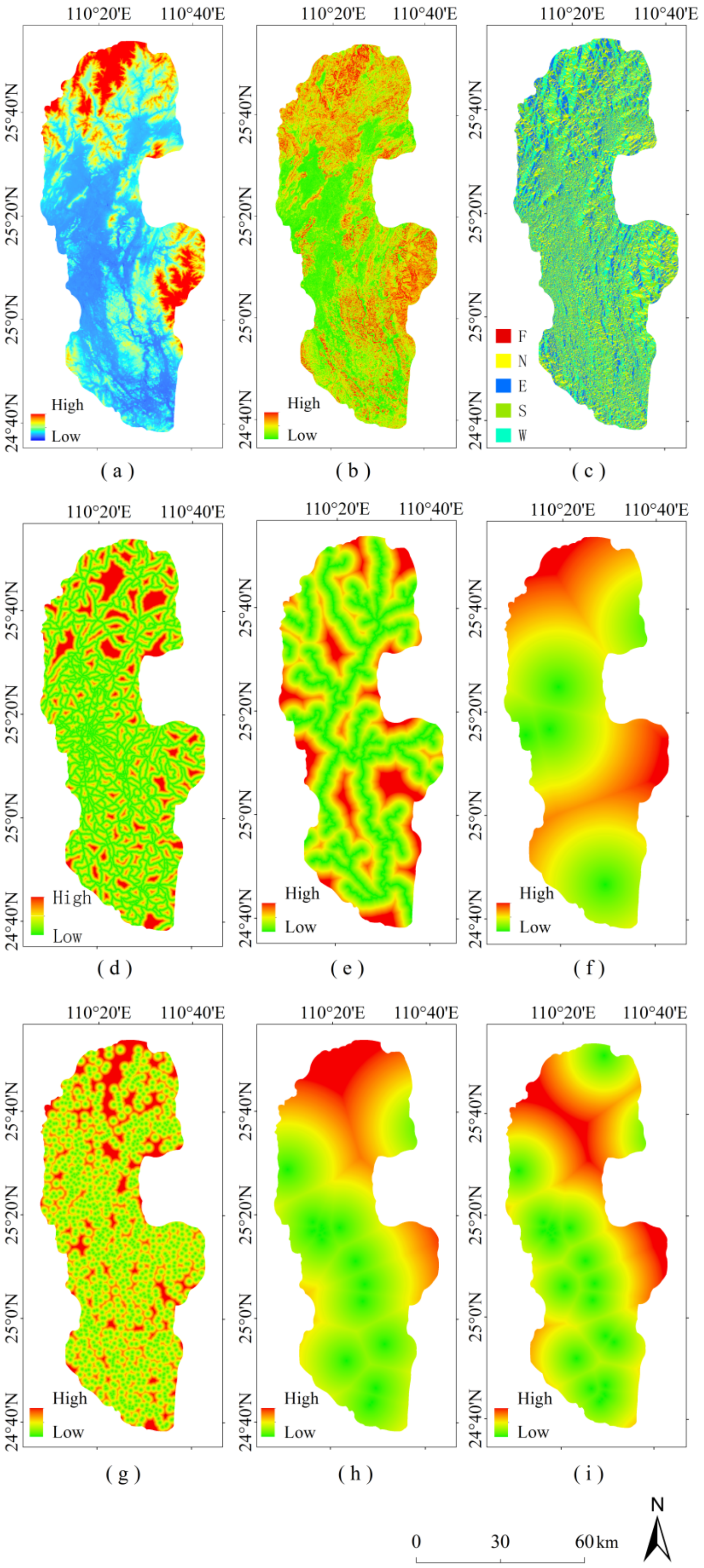

Figure 4 The spatial differentiation of the driving factors of land-use changes (a) Elevation; (b) Slope; (c) Aspect; (d) Distance to major road; (e) Distance to major river; (f) Distance to urban area; (g) Distance to residential area; (h) Distance to scenic spot in 2000; (i) Distance to scenic locations in 2010.

Table 1 **A description of the independent variables in the regression model**

Variables	MU	Description
Elevation	Raster Unit[a]	Relative elevation in each land unit
Slope	Raster Unit	Relative slope in each land unit
Aspect	Raster Unit	Aspect of each land unit.
Dis_Urban	Raster Unit	Relative distance from each land unit to urban areas
Dis_Rs	Raster Unit	Relative distance from each land unit to residential areas
Dis_Rd	Raster Unit	Relative distance from land unit to roads
Dis_River	Raster Unit	Relative distance from land unit to rivers
Dis_SSpot	Raster Unit	Relative distance from land unit to scenic spots ranked higher than AAA level
Population	County	Increment of population of each county during study period
GDP	County	Increment of Gross Domestic Product of each county during study period
TI	County	Increment of tourism income of each county during study period
FAI	County	Increment of fixed assets investment of each county during study period
XA	County	1 if land use unit belongs to Xing'an county, 0 otherwise
LC	County	1 if land use unit belongs to Lingchuan county, 0 otherwise
GL	County	1 if land use unit belongs to Guilin county, 0 otherwise
LG	County	1 if land use unit belongs to Lingui county, 0 otherwise
YS	County	1 if land use unit belongs to Yangshuo county, 0 otherwise

Notes: [a] Raster Unit is a pixel in 30 m×30 m; MU = Measurement Unit

values closer to 1 suggest better prediction ability and accuracy.

3 Results

3.1 Overall land-use change

Woodlands and cropland predominate the Li River Basin, and the percentage of this land that was under construction was generally small (i.e., below 3%; Table 2). However, there was dramatic growth in the area of land under construction, especially from 2000 to 2010, with an annual average growth rate of 6.93%. Cropland areas decreased from 1989 to 2000 but slightly increased from 2000 to 2010. However, woodland areas increased dramatically from 1989 to 2000, but slightly decreased from 2000 to 2010. Grasslands showed a remarkable decrease from 398.96 km^2 in 1989 to 300.75 km^2 in 2010. Aquatic areas remained stable during the first period; however, they decreased significantly during the second period due to local environmental changes and differences in climate conditions (e.g., runoff decreases and cropland reclamation from ponds).

A land use transition matrix (Table 3) was obtained by a comparing the patterns across 1989, 2000, and 2010. Over this time sequence, cropland simultaneously and significantly increased in some places and decreased in others, which indicates spatial reallocation. During the first period, new croplands primarily originated from woodlands and grasslands, with shares of 49.79% and 38.20%, respectively. During the second period, their shares changed to 58.60% and 30.46%, respectively; these changes indicate the increasing pressure of cropland reclamation on forests. Cropland was primarily lost to construction areas, woodlands, and grasslands. Contrary to the first period, the percentage of cropland lost to construction areas during the second period increased dramatically, which suggests an increasing speed of urbanization.

Woodlands have consequential ecosystem functions, and the growth of woodland fosters favorable conditions for the local environment. However, the loss of woodlands to croplands and construction areas increased though the total amount of forest remained stable. The percentage of woodlands converted to grassland during the first period was equal to the conversion amount during the second period, which indicates that increasing human activities significantly affected forest maintenance. Frequent transformations to croplands, woodlands, and grasslands suggest the increasing presence of intense human activities, including logging, cropland reclamation, and artificial afforestation. Moreover, these activities significantly interfere with land-use change.

Croplands are the most important source for construction expansion and comprised 82.17% of the area of new construction sites during the first period; however, this figure decreased to 57.92% during the second period. Accordingly, the expansion of construction occupied more woodland and aquatic areas.

Table 2 Land-use structures of the Li River Basin in 1989, 2000, and 2010 (Unit for area: km²; Unit for Ratio: %)

	1989		2000		2010	
	Area	Ratio	Area	Ratio	Area	Ratio
Cropland	1495.61	28.19	1415.58	26.68	1434.18	27.03
Woodland	3226.07	60.80	3334.49	62.84	3329.42	62.75
Grassland	398.96	7.52	351.89	6.63	300.75	5.67
Water body	137.96	2.60	137.28	2.59	111.14	2.09
Construction Land	47.45	0.89	66.81	1.26	130.57	2.46

Table 3 The land use transformation matrices for 1989~2000 and 2000~2010[a] (Unit : km²)

Period	Land Type	Crop-L	Wood-L	Grass-L	Water-B	CL
1989~2000	Cropland	1200.61	199.55	54.34	14.64	26.47
	Woodland	107.04	2981.65	130.54	4.77	2.08
	Grassland	82.12	148.40	166.47	0.46	1.52
	Water body	16.86	3.18	0.11	115.68	2.15
	CL	8.69	1.72	0.44	1.74	34.59
2000~2010	Cropland	1194.12	129.58	39.62	5.95	46.31
	Woodland	140.68	3046.09	131.51	3.96	12.25
	Grassland	73.13	147.01	127.26	0.39	4.10
	Water body	13.53	5.25	0.77	100.27	17.47
	CL	12.72	1.48	1.59	0.57	50.44

Notes: [a] Rows reflect the data of base period, and lines reflect the data of target period; Crop-L = Cropland; Wood-L = Woodland; Grass-L = Grassland; Water-B = Water-Body; CL = Construction Land

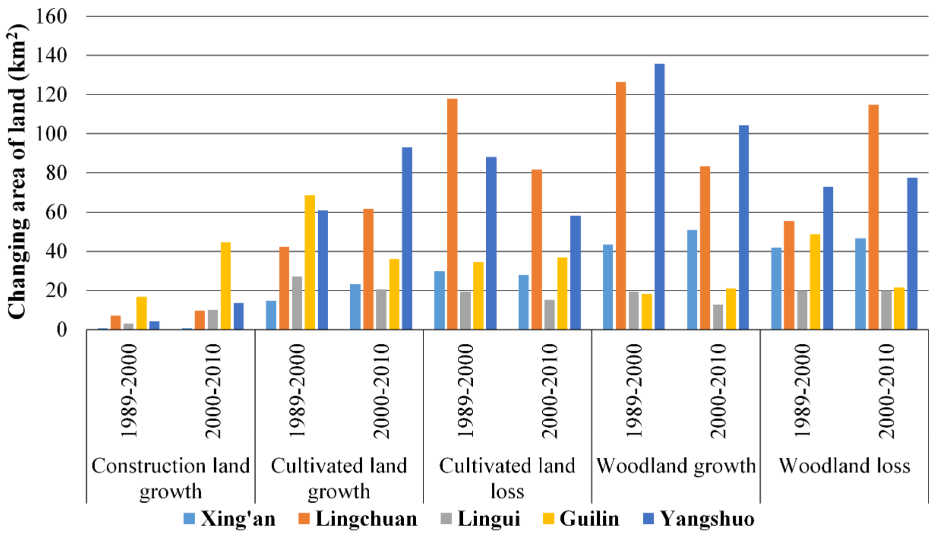

Figure 5 Land-use changes at the county-level (Unit: km²).

Quantitative changes of each land types at the county level revealed that construction expansion was primarily distributed in the middle and lower reaches of the Li River (Figure 5). Yangshuo and Lingui Counties as well as downtown Guilin exhibited a dramatic increase in construction expansion from 2000 to 2010. Because the built-up areas of Xing'an County are located outside the boundary of the basin, its expansion was relatively small. On average, more cropland was lost than gained. Lingchuan County, which is located in the upper reaches of the basin, suffered the most severe loss of cropland. Similarly, Xing'an County, which is also in the upper reaches of the basin, exhibited a continuous net loss of cropland from 1989 to 2000 and from 2000 to 2010. On average, more woodlands were gained than lost. However, their distribution was spatially and temporally uneven. Yangshuo and Lingchuan Counties showed the most woodland growth between 1989 and 2000; however, this amount declined significantly between 2000 and 2010. Moreover, woodland loss in Lingchuan County exceeded woodland growth between 2000 and 2010.

In general, land-use change in the Li River Basin over the past two decades exhibited two characteristics: (1) the rapid growth of construction, which contributed to a great loss of woodlands and croplands, and (2) intensified human activities, which leads to frequent transformations of croplands, woodlands, and grasslands. These characteristics indicate the increasing pressure of human activities on local land use and eco-system functions in the Li River Basin.

Table 4 Regression results of the distribution of new construction land

	Model I (level-1)		Model II (level-1 and 2)	
	1989~2000	2000~2010	1989~2000	2000~2010
Fixed Part (Coefficients)				
Level-1 (Land Unit)				
Elevation	-24.782^a	-20.436^a	-29.114^a	-22.583^a
Dist_Urban	-3.430^a	-1.784^a	-3.301^a	-2.099^a
GDP × Dis_Urban	-2.731^a	—	-8.347^a	—
Dis_Rd	-9.043^a	-2.305^a	-11.156^a	-2.547^a
Dis_SSpot	-1.918^a	-2.039^a	-1.936^a	-2.187^a
Level-2 (County)				
Population	—	—	3.110^a	—
FAI	—	—	—	1.942^a
Random Part (Variation)				
U_0	1.529	0.820	0.053	0.061
ROC	0.939	0.874	0.955	0.901

Note: ^{a} reflects significance of the coefficient is below 0.01.

3.2 Construction land changes

Newly added construction was primarily distributed within the middle and lower reaches of this basin, including downtown Guilin as well as Lingui and Yangshuo Counties. The expansion of construction moved north and west; thus, the distance between downtown Guilin and Lingui County grew narrower. According to the null model, the ILCCs of the construction change during the first and second periods were 0.52 and 0.49, respectively. These statistics indicates that individual and group effects influence changes in construction. Therefore, a multilevel logistic regression model was employed (Table 4).

All Level-1 variable coefficients were negative, which indicates that new construction tended to be located in areas close to urban areas, roads, and scenic locations. The negative coefficients of the interaction term suggest that an economic difference among counties would reinforce the effect of urban areas. In counties with flourishing economies, additional construction is most likely to grow near the urban areas. When including population and investment in the second level (Model II), the population coefficient was positive; this indicates that construction expansion tended to occur in counties with increased populations. This finding illustrates that population was an important driving force of construction expansion during the first period.

According to the result obtained for the second period, the coefficients for elevation, distance to urban areas, distance to roads, and distance to scenic locations were significant. This result matches that of the first period; however, the interaction term was excluded from the model. In Model II, the coefficient for fixed asset investments was positive, which indicates that construction land expansion tended to occur in counties with greater investments in infrastructure, factories, and so on.

Comparing the results of Models I and II, the Level-2 variables decreased the variation of the error term, which suggests that Model II provided a better fit. In general, the distribution of new construction primarily exhibited two characteristics: (1) new construction tended to be located near urban areas, roads, and scenic locations with lower elevations, and (2) the distribution of new construction land was uneven among the different counties. Economic growth and population positively affected the probability of construction land expansion during the first period, whereas fixed assets investments were the primary driving force during the second period. The driving forces of construction land expansion showed a county-level shift from population to investment.

3.3 Cropland changes

According to the null model, the ILCCs of cropland reclamation were 0.28 and 0.21 for the first and second periods, respectively, whereas the ILCCs for the croplands that participated in the *Grain-for-Green Policy* were 0.10 and 0.09, respectively. These ILCCs illustrate that differences among land units, rather than those among counties, primarily influence cropland changes. Therefore, a conventional logistic regression was used to explore the factors that influence cropland change.

The regression revealed that slope and elevation are key factors that influence the distribution of cropland changes (Table 5). Cropland reclamation tended to be located in the areas with low altitudes and gentle gradients. However, croplands that participated in the *Grain-for-Green Policy* were generally distributed in other areas, thereby matching this policy's target, which emphasized afforestation through the abandonment of unsuitable croplands, such as those with slopes greater than 25°. Moreover, aspect played a significant role in cropland reclamation, which tended to occur on eastern and southern slopes. The distribution of cropland reclamation exhibited different characteristics between the first and second periods. Cropland reclamation primarily occurred near roads during the first period; however, the peripheries of urban areas and scenic locations attracted more cropland reclamation during the second period. The dummy variable coefficients of counties revealed that the cropland in the upper reaches suffered great losses across the entire study period. Similarly, the cropland in the middle reaches decreased gradually with rapid urbanization. In the lower reaches of the basin, cropland underwent a dramatic decrease from 1989 to 2000, but increased from 2000 to 2010.

Table 5 **Regression results of the cropland change distribution**

Independent variables	**Cropland reclamation**		**Cropland participating to "Grain for Green" Policy**	
	1989~2000	**2000~2010**	**1989~2000**	**2000~2010**
Elevation	-25.743^{a}	-10.270^{a}	9.043^{a}	16.845^{a}
Slope	-2.794^{a}	-2.571^{a}	4.228^{a}	5.289^{a}
Aspect_North	—	—	—	—
Aspect_East	0.622^{a}	0.825^{a}	—	—
Aspect_South	0.735^{a}	1.013^{a}	—	—
Aspect_West	—	—	—	—
Aspect_Flat	—	—	—	—
Dis_Rd	-2.350^{a}	—	1.020^{b}	—
Dis_Urban	—	-1.004^{a}	-1.284^{a}	—
Dis_Rs	—	—	2.222^{a}	1.678^{a}
Dis_SSpot	—	-0.957^{a}	—	—
XA	-0.666^{a}	—	—	—
LC	-1.265^{a}	—	0.418^{a}	0.563^{a}
GL	—	—	-0.723^{a}	—
LG	—	0.704^{a}	—	—
YS	—	0.489^{a}	—	0.392^{a}
ROC	0.931	0.838	0.810	0.823

Notes: ^{a} reflects significance of coefficient is below 0.01 and ^{b} reflects significance of coefficient is below 0.05.

Most of the cropland participating in the *Grain-for-Green Policy* was located near the urban areas and in areas away from roads and residential areas during the first period. However, the influence of urban areas and roads decreased and abandoned croplands were primarily distributed away from residential areas.

In general, the cropland in the Li River Basin decreased in a non-uniform way. Simultaneously, croplands were spatially reallocated. For example, cropland reclamation was distributed near roads during the first period, whereas the croplands associated with the *Grain-for-Green Policy* were located away from roads. The croplands in steep, undulating areas were abandoned and afforested, whereas cropland reclamation was distributed in areas with gentle gradients. Spatial reallocation is favorable for promoting land-use efficiency and facilitating the efficient use of local land resources.

3.4 Woodland changes

The transfer matrix analysis of land-use change revealed that woodland change is a relatively complicated process. To reveal the detailed characteristics of woodland change, variable trajectories from 1989 to 2000 and from 2000 to 2010 were tracked. Accordingly, woodlands were divided into eight categories (Table 6). Land-use change did not occur among Category I (stable woodlands) and II (non-woodlands). Stable woodland comprised 52.66% of the study area, and these areas were primarily located in the upper reaches of the basin. Categories III and IV denote the woodland changes that occurred from 1989 to 2000: the latter woodlands (stable regrowth woodlands) were located in Lingchuan County and Yangshuo County, whereas the former area (permanent woodland loss) was distributed in downtown Guilin as well as Lingchuan and Yangshuo Counties. Category IV areas were larger than Category III areas. The stable regrowth woodlands in Yangshuo County

Table 6 Each woodland types in the classification of changing trajectory (Unit: km²)

Classification	**Changing trajectory**			**Upper reaches**		**Middle reaches**		**Lower reaches**	**Li River Basin**
	1989	**2000**	**2010**	**Xing'an**	**Ling chuan**	**Lingui**	**Guilin**	**Yangshuo**	
I (F-F-F)	F	F	F	843.89	1163.94	89.10	97.43	480.14	2794.35
II (N-N-N)	Non	Non	Non	134.90	484.20	138.12	343.00	438.47	1552.53
III (F-N-N)	F	Non	Non	17.17	27.85	13.63	37.64	38.18	135.70
IV (N-F-F)	Non	F	F	31.55	88.69	12.41	9.99	101.34	251.74
V (F-F-N)	F	F	Non	34.76	77.38	12.92	13.37	43.22	187.29
VI (N-N-F)	Non	Non	F	26.11	55.66	6.41	10.07	69.44	174.60
VII (F-N-F)	F	Non	F	24.79	27.66	6.27	11.05	34.83	108.72
VIII (N-F-N)	Non	F	Non	11.96	37.54	7.00	8.10	34.38	101.10

Notes: Here "F" and "Non" refer to two different woodland types; F = Forest; Non = Non-forest.

were greater than those in other counties due to the implementation of several ecological projects since 1991, such as the project that closed hillsides to facilitate afforestation along the Li River and near major scenic location.

Categories V and VI denote the woodland change occurring from 2000 to 2010: the latter areas represent recent regrowth woodland, whereas the former areas represent new woodland clearing. The Category V areas in the upper reaches of the basin were larger than the Category III areas, and the Category IV areas were smaller than the Category VI areas. These results suggest that woodland clearing increased in the upper reaches of the basin. Similarly, although woodlands in the lower reaches continue to increase, their growth rates show signs of reduction. These phenomena suggest the presence of pressures to convert forests in the Li River Basin.

Categories VII and VIII denote two types of fluctuating woodland changes. Category VII represents old forest regrowth with recent clearing, whereas Category VIII represents new clearings with recent regrowth. Both of these areas are larger in Yangshuo and Lingchuan Counties, which indicates that the woodlands in these counties are unstable, given the interference of human activities with regard to woodland change.

According to the null model, the ILCCs of Categories III, IV, V, VI, VII, and VIII were 0.29, 0.19, 0.04, 0.16, 0.03, and 0.04, respectively. These statistics reveal that the woodland changes over the entire study period were more affected by individual than group differences. The ILCC of woodland change during the first period was larger than that of the second period, which indicates that woodland change became more prevalent in the Li River Basin: thus the between-group effect faded. Because the ILCCs were relatively small, a conventional logistic regression model was employed to analyze woodland change.

The regression results showed that elevation, slope, aspect, distance to rivers, distance to roads and distance to scenic locations predicted the distribution of woodland regrowth (i.e., Categories IV and VI; Table 7). The dummy variable coefficients of aspect indicated that forest regrowth tended to occur on southern slopes whereas forest regrowth on northern slopes was less likely. The coefficients of these factors were positive, which indicates that woodland regrowth tended to be located in areas away from roads, rivers, and scenic locations. The coefficient of the interaction term of tourism income and distance to scenic locations was negative, which is in contrast to the coefficient of distance to scenic locations. This result suggests that the woodland regrowth in more developed counties is relatively closer to scenic locations than that in less developed counties. This result corresponds to the tourism development in the Li River Basin, which relies on the utilization of natural tourism resources, including forest landscapes. However, the positive coefficient of distance to scenic locations illustrates the general and significant interference of tourism development on woodland changes. The coefficients of the interaction term between GDP and the distance to urban areas among Category IV and VI differed, which suggests that the woodland regrowth near urban areas is distributed differently. Woodland regrowth was primarily distributed closer to urban areas during the first period, and its extension might be greater in developed counties; however, woodland regrowth during the second period tended to show the opposite pattern.

Although Categories III and V both denote woodland clearing, they share influencing factors. During the first period, woodland clearing tended to be in areas near rivers and scenic locations but away from urban areas and roads. County economic growth narrowed the influence of extending construction into urban areas. Moreover, counties with flourishing tourism sectors broadened the influence of extending into scenic locations. During the second period, woodland clearing tended to occur along the roads with gentle gradients. The coefficients of other influencing factors were insignificant, which indicates that enhancing accessibility played an important role in woodland clearing.

The results concerning Categories VII and VIII (Table 8) indicated that fluctuating woodland changes tended to occur in locations near urban areas with lower elevations. Fluctuating woodland changes included woodland regrowth tended to be near scenic locations, whereas woodland clearing tended to be farther from scenic locations. Compared with the results from Categories III through VI, woodland regrowth at the periphery of scenic locations belonging to fluctuating woodlands and stable woodland regrowth did not generally occur near the scenic locations. Likewise, permanent woodland clearing tended to be near scenic locations. Thus, the construction of scenic locations negatively affected forest conservation in the Li River Basin.

Table 7 Regression results of the distribution of woodland changes

Variables	III (F-N-N)	IV (N-F-F)	V (F-F-N)	VI (N-N-F)
Elevation	—	4.810^{a}	—	4.927^{a}
Slope	-4.896^{a}	6.604^{a}	-2.853^{a}	4.502^{a}
Aspect_North	—	-0.504^{a}	—	-0.230^{a}
Aspect_East	—	—	—	-0.202^{a}
Aspect_South	0.249^{a}	0.258^{a}	0.440^{a}	—
Aspect_West	—	—	—	—
Aspect_Flat	—	—	—	—
Dis_Urban	0.915^{a}	-1.995^{a}	—	0.984^{a}
GDP×Dis_Urban	-3.478^{a}	4.745^{a}	—	-2.087^{a}
Dis_Rv	-0.927^{a}	2.350^{a}	—	0.960^{a}
Dis_Rs	—	1.024^{a}	—	—
Dis_Rd	1.401^{a}	1.725^{a}	-1.299^{a}	0.791^{b}
Dis_SSpot	-4.229^{a}	1.366^{a}	—	0.941^{a}
TI×Dis_SSpot	16.116^{a}	-20.114^{a}	—	-2.092^{a}
ROC	0.820	0.845	0.633	0.778

Notes: ^{a} reflects significance of coefficient is below 0.01 and ^{b} reflects significance of coefficient is below 0.05.

Table 8 Regression results of the distribution of unstable woodlands

Variables	VII (F-N-F)	VIII (N-F-N)
Elevation	-3.447^{a}	-4.304^{a}
Slope	2.575^{a}	-1.665^{a}
Aspect_North	—	—
Aspect_East	—	0.130^{a}
Aspect_South	0.219^{a}	0.299^{a}
Aspect_West	0.152^{a}	—
Dis_Urban	1.443^{a}	0.782^{a}
Dis_Rv	1.666^{a}	1.272^{a}
Dis_SSpot (1989~2000)	0.744^{a}	-4.675^{a}
Dis_SSpot (2000~2010)	-0.385^{b}	3.190^{a}
ROC	0.655	0.652

Notes: ^{a} reflects significance of coefficient is below 0.01 and ^{b} reflects significance of coefficient is below 0.05.

4 Discussion

In terms of coupled human-environment system, the previous literature strives to integrate the eco-environmental and socio-economic factors into the LUCC (Land Use/Cover Change) analysis, especially those that employed a regression technique. However, the achievement towards this goal is subject to the different specificity of the dataset of physical and anthropogenic factors. Within the study of land-use change, physical data usually come from remote sensing dataset or maps, whereas most of the anthropogenic data are based on census or social survey. When analyzing the land-use change at small scales (e.g. field level or household level), current research had to use a series of distance-based proxy or interpolation data to represent socio-economic factors (Bai et al. 2004; Xie and Li 2008). When analyzing the land-use change at large scales (e.g. provincial level or national level), they had to calculate the average natural status of a region according to the administrative boundary with which the characteristic does not necessarily match (Liu et al. 2005). Despite the fact that these techniques are widely used and seem to be effective, they could not answer how regional difference (e.g. difference in economic performance, population growth, human livelihood and welfare, and technology development) may affect the land dynamics. We found that regional differences do matter in practice. In the first period, population growth was the most important driver for construction land expansion, whereas investment in infrastructure became the primary driver in the second period. These results indicate that differences at the regional level can be important in analyzing land dynamics at the field level. They also embraced the recent accentuation of scale issues from LUCC scientists (Veldkamp and Lambin 2001; Cai 2001; Overmars and Verburg 2006). In this sense, multi-level statistics offers a feasible alternative for us to consider the inter-level interaction.

Notwithstanding the capability of multi-level statistics to deal with dataset of different specificities, there are still some noteworthy aspects of our model. As everyone knows, regression techniques reveal correlation rather than causation. It reminds us to be prudent in our explanations, since the multi-level statistics is a form of regression technique. On the other hand, within our research, a multilevel logistic model was applied to construction areas and a conventional logistic model was used for croplands and woodlands. It seems that the multilevel logistic regression model might be more applicable with regard to the determining socio-economic driving forces of increased construction. However, it does not necessarily mean multi-level logistic regression won't be feasible for cropland or woodland. It just indicates that the croplands and woodlands in Li River Basin were affected by topography and accessibility more than socio-economic diversity. In fact, several studies have reported a significant effect of regional economic performance on croplands and woodlands (Long et al. 2007; Li et al. 2013).

5 Conclusion

Using the Li River basin as a case study, this paper seeks to analyze the distribution of land-use-change between 1989 and 2010 and examine its potential driving factors. Driving forces can be categorized into three major types: First, topography is a primary predictor of land-use change in the Li River Basin (which is a Karst landform). Second, urban and residential areas as well as roads, rivers, and scenic locations significantly affect land-use changes. These effects exhibit more significance and regularity for land-use types dominated by human activities (e.g., construction areas and cropland), whereas the effects on land-use types with more natural attributes are less significant and regular (e.g., woodlands and grasslands).

Finally, as a tourist region, tourism development manifests a significant effect on regional land-use change. Our research analyzed two major effects of tourism: the construction of scenic locations and county income due to tourism. It reveals that the construction of scenic locations affects the distribution of land-use change directly and facilitates the transformation of other land-use types into construction land near scenic locations. Moreover, the construction of scenic locations interferes with woodland change, which leads to an increase of unstable woodland regrowth and permanent woodland clearing near scenic locations. On the other hand, the differences among counties with regard to tourism income also affect land-use change, especially for woodlands. Although the construction of scenic locations can increase the pressure to convert forests, the growth of tourism development helps to narrow the extension of scenic locations. This conclusion corresponds to the tourism characteristics of the Li River Basin that rely on natural resources. However, tourism development is associated with population growth and increased demands for infrastructure. Accordingly, the effects of population growth and investments on local infrastructure might trigger construction expansion.

Generally, the case study has shown that multilevel logistic regression is able to deal with the diverse specificity of driving forces dataset of land dynamics. Building on this premise, we are able to use regression techniques to analyze land-use change in terms of coupled human-environment systems. Subject to the data, we only considered the driving forces at the field-level and the county-level. In fact, multilevel statistics is able to incorporate three hierarchical levels simultaneously. It can also analyze the cross-level effects. Therefore, it has the potential to analyze land-use change at coupled field-household-regional levels, or to explore the cross-scale proposition of land-use change, as its feasibility awaits proof by further empirical study.

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