

Spatiotemporal dynamics of LUCC from 2001 to 2010 in Yunnan Province, China

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Abstract. LUCC (Land use and land cover change) is increasingly regarded as an important component of global environmental change and sustainable development. In this study, regional land cover type maps were drawn using the MODIS products from 2001 and 2010 based on the modified classification scheme embodied by the characteristics of land cover in Yunnan. Dynamic change in each type of land cover was investigated by classification statistics, dynamic transfer matrices, and landscape pattern metrics. In addition, the driving factors of LUCC were discussed. The results showed that the land cover types of the Yunnan province, especially woodland (WL), cropland (CL) and grassland (GL), had experienced noticeable changes with an area of about 30% of land during the study period. And there was an obvious vertical distribution pattern for land cover types. The average altitude of different land cover types from the highest to the lowest were unused land (UUT), WL, GL, water (WT), urban and built-up areas (UB) and CL. The average slope for most of the land-cover types did not vary over the past 10 years. Stabilization and homogenization will be the direction of land cover in the future according to landscape metrics analysis. The regional differences of land use structure in the area are strongly influenced by such factors as the geographical position, level of economic development and land use policy. The new policy of land use, Construction of Mountainous Town, would be provided to achieve the economical and intensive utilization of land resources during the rapid development of urbanization and industrialization in Yunnan.

Key words: LUCC, landscape, MODIS, Mountainous Town, Yunnan



1. Introduction

Land surface conditions impact the regional and global climate through the water cycle and surface-energy budget [1, 2]. LUCC (Land use and land cover change) has become one of the focuses of global environmental change research, which is bound up with the environmental changes and socioeconomic development [3-5]. Regional land cover changes in the developed areas of Eastern China have been paid wide attention with the urbanization and industrialization development since a series of policy implementation in China [6-9]. While land cover changes in Western China have been drawn little concern, particularly with regard to the whole area of Yunnan with complex terrain.

The Yunnan province constitutes the majority of the Yunnan-Guizhou Plateau, accounting for 94% of the mountain and 6% of the plain, and the vertical zone from low to high elevation gradients can be divided into low heat, middle warm, high cold sectors [10]. As a result of typical climate changes and human activities, land cover in the Yunnan province differs from the other area of the same latitude [11]. Some researchers have discussed the land use change of cities, counties and some small watershed. Li et al. [12] studied LUCC from 1976 to 2003 in Xishuangbanna of Yunnan Province, clarified the impacts of land-use change on biomass carbon dynamics, and explored how the alternative land-use scenarios could influence future carbon budgets. Hu et al. [13] analyzed the changes in the ecosystem in relation to LUCC in the Menglun Township in Yunnan, using Landsat TM/ETM and Quickbird dataset from 1988 to 2006. They found that an abrupt variation in land use from ecologically important tropical forests and traditionally managed swidden fields to large scale rubber plantation brought about large losses of ecosystem services in this area. Xu et al. [14] investigated the impacts of local government-driven reforestation on LUCC, as well as its further impacts on livelihoods of upland farmers in Xizhuang watershed by aerial photographs and ASTER satellite imagery for a 15-year period (1987-2002). Fox and Vogler [15] summarized LUCC at eight sites in Montane Mainland Southeast Asiain, including three sites in Yunnan, over the last 50 years. They found that land use and land cover had maintained stable and the minor amount of land use had transfered from swidden to monocultural cash crops. They suggested that two forces, national land tenure policies and market pressures, would increasingly determine land use systems.

Many land cover change researches in Southwestern China have concentrated on counties or small watershed. Land cover change of the whole province on a large scale has not been reported yet. This deficiency is an obstruction of the development and utilization of land resources, ecological environment security, climatic change adaptation and water resource management of this area especially since the implementation of the western development strategy. To cover the shortage, we discuss the temporal and spatial variation of LUCC using datasets in Yunnan province between 2001 and 2010 and its driving forces in this study.

The goals of this paper were to study dynamic change in each type of land cover by classification statistics, dynamic transfer matrices and landscape pattern metrics, and to discuss the driving forces of this change. The study is organized as follows. "Data and methods" shows the study site, data collection and methods. "Results and discussion" displays the land cover change results using different methods, and discuss its driving forces. "Conclusions" draws conclusions according to the results.

2. Data and methods

2.1. The study site

Yunnan province is situated in the southwest of China between 97°31' and 106°11'E, and 21°8' and 29°15'N, covering an area of 394,100 km², with elevations ranging from no less than 100 m to 6740 m. Its topography is complex, with over 84% of the total land consisting of mountains, plateaus and hills accounting for 10% of the total land, and less than 6% of the total land composing of local plains (commonly known as "Bazi") and lakes. Three basins are covered in the Yunnan province, namely the Yangtze River Basin, the Pearl River Basin and the Southwest Region Basin. Among them, the Pearl River and the Red River originated from the region (Figure 1).

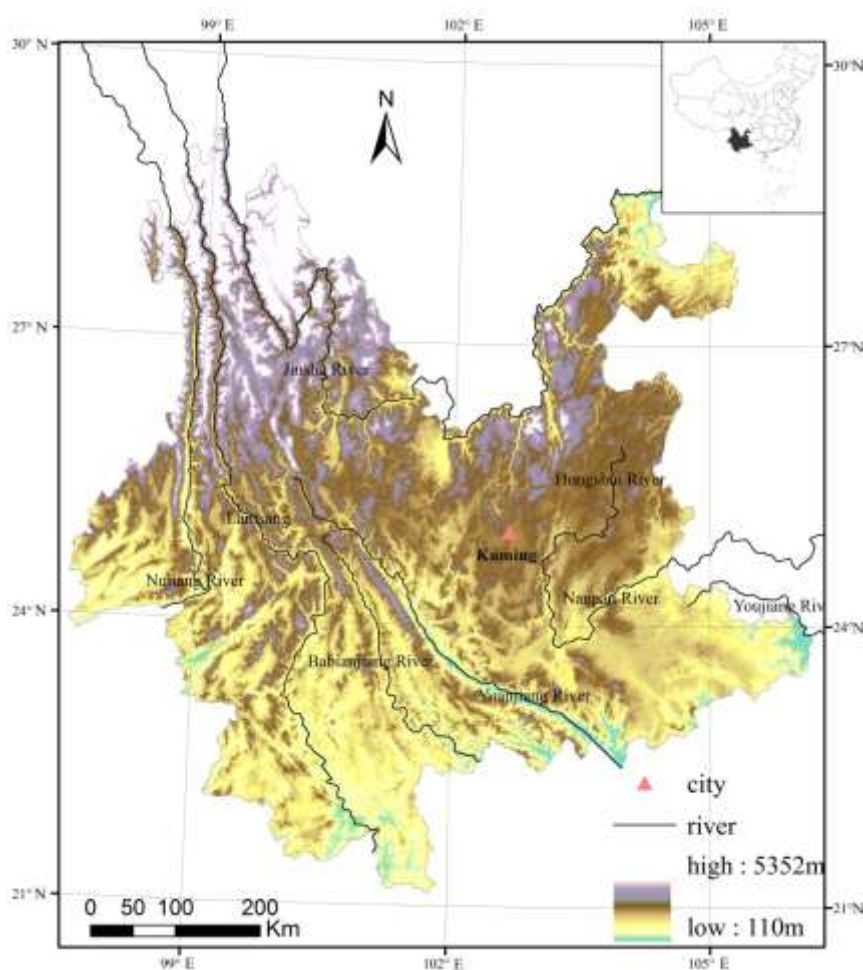


Figure 1. Location of the study area.

The climate of the Yunnan is affected by geographical position and altitude with tropical, temperate zones and highland climate zones, characterized by intense solar radiation and high daily variations in temperature, but low annual temperature fluctuations. The average maximum monthly (July) temperature is 22°C, and the average minimum (January) temperature is 6°C, with a mean annual temperature of 12°C. The mean annual precipitation changes from 300 mm in Benzilan located in the Jinsha river valley, where is a typical dry river valley climate style, to 4,000 mm in the western

mountain with altitude more than 2000 m with most of the rainfall in June, July and August[16]. The vegetation mainly consists of tropical rain, seasonal rain, evergreen broad-leaf and cold temperate coniferous forests. The major soils include laterite, latosolic red, red, yellow, luvisols, and paddy soils. The province has a population of 45,966,000, and includes 25 minority nationalities, accounting for one third of the population.

The eco-environmental problems, such as ecological deterioration and soil degradation, have become more and more serious due to climate change and human activities in the recent years. These problems have been threatened the regional economic development and social well-being. This study intends to describe the temporal and spatial changes of LUCC in the Yunnan province for a 10-year period with the hope that the results can be useful for recognizing the driving forces and understanding the eco-environmental feedback mechanisms that may assist decision-makers to find sustainable solutions to optimize landscape patterns for maintaining the ecological security of this region.

2.2. Datasets

The land cover datasets in this study were determined using the MODIS (MOD12Q1-051) data from 2001 and 2010 (<https://lpdaac.usgs.gov>). The International Geosphere-Biosphere Programme (IGBP) global vegetation classification scheme was used to describe the land use/cover types of the Yunnan province by combining the 17 categories into six types, including cropland(CL), woodland(WL), grassland(GL), urban and built-up areas(UB), water(WT) and unused land(UUL) (Figure 2).

The Digital Elevation Model (DEM) dataset was from Computer Network Information Centre, Chinese Academy of Sciences (<http://www.gscloud.cn>), and was used to derive the mean elevation and slope of the region.

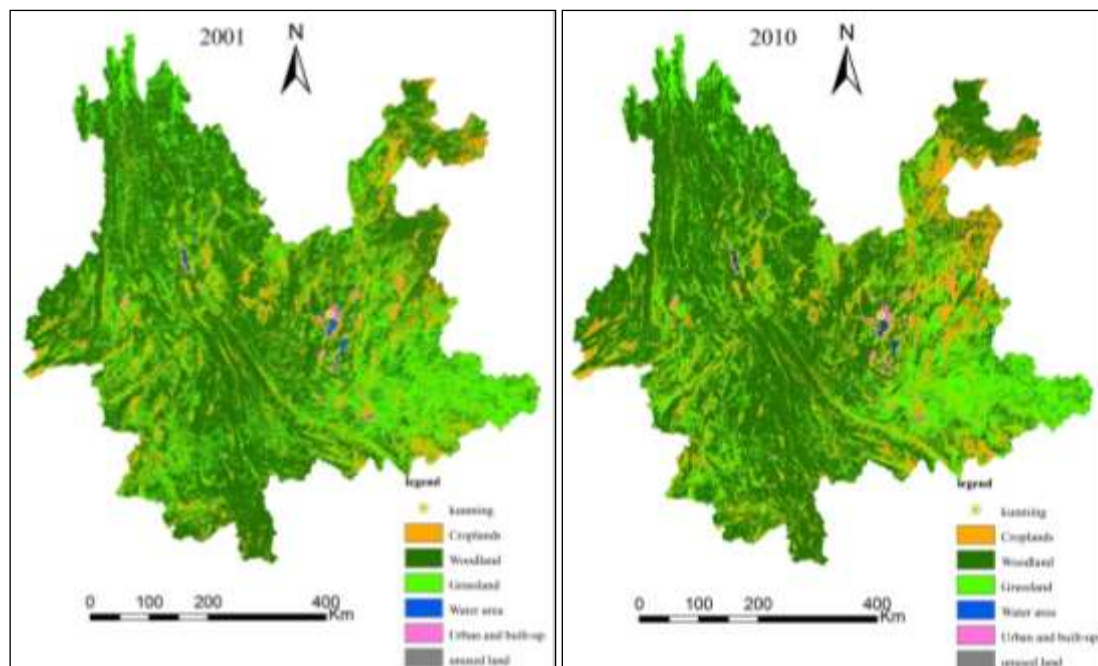


Figure 2. The land cover types in 2001 and 2010 in Yunnan province.

2.3. Methods

2.3.1 Methods for Land Use Change Analysis. Some existing models and indicators were used to calculate the extent and rate of LUCC [17, 18]. In this study, three models were selected to compute LUCC in the Yunnan province, a single dynamic index (k), a complex dynamic index (Lc) and a transition matrix [19, 20].

The single dynamic index (k) was used to compute the change of a specific type of land use. It was defined as

$$k = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

where k was the dynamic indicator for a specific type of land use/cover. U_a and U_b were the areas of the specific land use/cover type at the start time and at the end time. And T was the time scale under consideration.

The complex dynamic index (Lc) was used to describe the regional differentiation of land use change rate, which was derived as

$$Lc = \left(\frac{\sum_{i=1}^n \Delta LU_{i-j}}{2 \sum_{i=1}^n LU_i} \right) \times \frac{1}{T} \times 100\% \quad (2)$$

where LU_i was the area of land use/cover type i at the start date. ΔLU_{i-j} was the area turning from type i to type j in the computing period ($i \neq j$). n was the number of the land use/cover types. and T indicated the monitoring period. If T was 1 year, Lc was the comprehensive land use/cover dynamic degree in the region.

The land use transition matrix came from the quantitative description of the status and status transition system during the system analysis [21, 22]. In this study, the transition matrix was adopted to conduct a trend analysis of land cover dynamics. The transition matrix and the cross-classification map were calculated by the Raster Calculator module of the software ArcGIS.

2.3.2 Landscape metrics. Landscape pattern analysis, which is based on geometrical features, can actually display the spatial pattern of LUCC and its impact on landscape ecology [23, 24]. Two groups of landscape metrics, including class level metrics and landscape level metrics, were computed using

the FRAGSTATS software programmed by the Forest Science Department, Oregon State University, U.S.A. At the class level, three aspects were used to describe the characteristics of the landscape pattern, including area-edge metrics (LPI), shape metrics (PAFRAC) and aggregation metrics (NP, PD, IJI and CONHESION). At the landscape level, four aspects were used, including area-edge metrics (TA, LPI), shape metrics (Shape_AM), aggregation metrics (NP, PD, IJI, ENN_MN, CONTAG, CONHESION and SPLIT) and diversity metrics (SHDI). Although many indices have counterparts at the class and landscape levels, their interpretations may be somewhat different. Class metrics represent the spatial distribution and pattern within a landscape of a single patch type, while landscape metrics, considering all patch types simultaneously, represent the spatial pattern of the entire landscape mosaic. Most of the class indices can be observed as fragmentation indices because they measure the configuration of a particular patch type, whereas most of the landscape indices can be interpreted more broadly as landscape heterogeneity indices because they describe the overall landscape pattern [25].

3. Results and discussion

3.1. Analysis of LUCC

The main land cover types in the Yunnan province included WL, GL, and CL, probably 99% of the total land area as shown in Table 1. Among them, the WL area reached more than half of the total area. WT and UUL were the least common land types. In Figure 2, WL was mainly distributed in the middle and northern area of the Yunnan province, while GL was mostly focused in the southeast in 2010. CL was mainly located in the northeast, although it was also scattered in other places. The spatial distribution pattern was determined by the Yunnan region's unique geography and climate.

Table 1. The land cover types in Yunnan in 2001 and 2010.

land cover types	2001		2010		Change		Rate of Change	
	Area (km ²)	Percent (%)	Area (km ²)	Percent (%)	Area (km ²)	Percent (%)	K (%)	Lc (%)
CL	51576.75	13.42	59404.25	15.46	7827.5	15.18	1.686	0.39
WL	219757.25	57.18	224971.75	58.54	5214.5	2.37	0.264	2.3
GL	108574.75	28.25	95527.25	24.86	-13047.5	-12.02	-1.335	3.14
WT	1174.75	0.31	1248	0.32	73.25	6.24	0.693	5.16
UB	3017.25	0.79	3018	0.79	0.75	0.02	0.003	1.21
UUL	231.5	0.06	163	0.04	-68.5	-29.59	-3.288	1.02

The land cover statistics were used to describe the quantitative change of land cover. From Table 1, it was quite noticeable that the quantity of WL, CL and GL changed obviously during the past 10 years. The area of CL increased from 13.42% in 2001 to 15.46% in 2010 i.e., by 7828 km². The area of WL, the dominant land cover type, grew slightly from 57.18% in 2001 to 58.54% in 2010 i.e., by 5421 km². However, the area of GL greatly decreased from 28.25% in 2001 to 24.86% in 2010, representing a loss of approximately 13,047 km². The area of WT, UB had changed insignificantly.

The area of UUL had dramatically changed over the past 10 years, accounting for a smaller proportion of the total area.

To represent the change speed of land cover, we put to use formulas 1 and 2 to calculate k and Lc , and the results were presented in Table 1. According to k , the change speed of CL, WLL and UUL were fast. Among them, other types were transformed to CL, and the annual area variation for this area was 1.69% contrasted with a corresponding area in 2001. GL as well as UUL was converted into other types, with the annual rates of 1.34% and 3.29%, respectively. The complex dynamic index over the past 10 years was 1.74%. Overall, some changes took place in the regional land use.

For a better explanation of each type of land use transfer to other major types, transfer matrices were used (Table 2), including the area variation and percentage compared to the corresponding area in 2001. It could be observed that CL, WL and GL were largely transformed to other land cover types from 2001 to 2010. Among them, the transformation between WL and GL was the strongest. The area of GL transformed to other types was the largest and reached 53821.3 km². The percentage of UUL transformed to other types, which corresponded to the area in 2001, was the largest at 55.55 %. From 2001 to 2010, CL was especially transformed to WL and GL, of which the area added up to 24,477.6 km², about 47.46% compared to the CL area in 2001. WL was primarily occupied by CL and GL with an area up to 41,008.6 km² or approximately 20.08% of the total WL area in 2001. To sum up, major land cover type transformations (Table 2) indicated that nearly 30 % of land cover had changed during the study period.

Table 2. Major land cover changes in the Yunnan from 2001 to 2010

Land cover types (2001)	Land cover transformation (2010)	Change of the area (km ²)	Percentage of the changed area compared to corresponding area in 2001 (%)
CL	WL	13047.10	22.16
	GL	11430.50	25.30
WL	CL	14307.60	7.01
	GL	26701.00	13.07
GL	CL	18335.50	8.98
	WL	35485.80	17.38
WT	CL	22.09	1.88
	WL	220.65	18.78
UB	CL	139.99	4.64
	GL	37.48	1.24
UUL	WL	23.83	10.29
	GL	104.78	45.26

The spatial transformation distributions of the major land cover types, including CL, WL and GL in the Yunnan from 2001 to 2010, were presented in Figure3. The changes from CL to WL occurred in

the northeast of the region and the transformation to other types was widely distributed throughout the region. The variation from WL to CL and GL mainly took place in the east. The conversion from GL to CL and WL mainly occurred in the west and east.

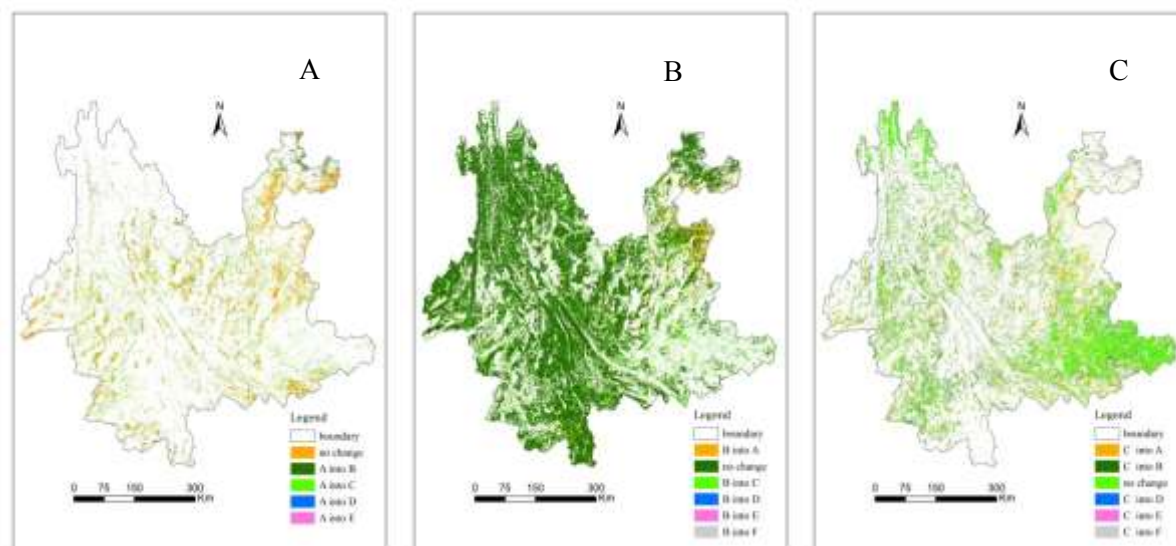


Figure.3 The major land cover types transition from 2001 to 2010.

(A:CL,B:WL,C:GL,D:WT,E:UB,F:UUL)

On the whole, the land cover types of the Yunnan during the study period had changed a lot. A major land cover variation happened when GL converted to WL, with an area variation up to 35485.8 km². Moreover, the percentage of UUL that transformed to GL is the largest, reaching 45.26 %.

Table 3. Elevation gradient changes of different land cover types in Yunnan.

land cover types	Average elevation gradient (m)			Area percentage (%)											
				Elevation gradient<2000 m						Elevation gradient>2000 m					
							2000 m-3000 m			3000 m-4000 m					
	2001	2010	Δ	2001	2010	Δ	2001	2010	Δ	2001	2010	Δ	2001	2010	Δ
CL	1655.	1633.	-21.	77.	76.	-1.4	21.	23.		0.6	0.2	-0.3	0.0	0.0	-0.0
	30	71	59	79	37	1	57	35	1.79	3	7	6	2	0	1
WL	1985.	1973.	-12.	54.	55.	0.2	35.	34.	-0.6	8.7	8.9	0.2	0.9	1.0	0.1
	22	19	03	93	20	7	40	76	3	0	6	6	7	7	0
GL	1779.	1761.	-17.	71.	72.	1.0	19.	18.	-0.9	5.4	5.2	-0.2	3.3	3.5	0.2
	71	88	83	60	60	0	63	64	9	6	0	7	1	6	5
WT	1736.	1697.	-38.	93.	92.	-0.8	5.7	6.6		0.8	0.7	-0.1	0.0	0.1	0.0
	34	40	94	31	44	7	6	8	0.92	5	2	2	8	6	8
UB	1705.	1707.		85.	85.	-0.0	13.	13.		0.4	0.4	0.0	0.0	0.0	0.0
	76	73	1.97	91	88	2	69	71	0.02	1	1	0	0	0	0
UUL	4106.	3747.	-358	19.	16.	-3.5	1.3	0.0	-1.3	6.2	10.	4.2	72.	73.	0.6
	67	77	.9	64	05	9	4	0	4	5	5	4	77	46	9

Δ : Difference

3.2. Land cover changes along with elevation and slope gradient

The distribution characteristics of land cover, which were closely related to the elevation gradient, were presented in Table 3. From the table, a prominent vertical distribution pattern in the Yunnan was summarized. The average elevation gradient of different land cover types from the highest to the lowest were UUL, WL, GL, WT, UB and CL.

CL, the lowest of land cover type in Yunnan with the average elevation gradient of 1600 m, was mostly distributed in the gentle-slope valleys below 1700 m with the comparatively lower elevation gradient and the relatively wetter and warmer climate, and this area was nearly 78% of the total CL area. The remaining area of CL was located between 2000 and 3000 m. About 55% of WL was distributed below 2,000 m, and 35% distributed between 2000 m and 3000 m. The average elevation gradient for WL was approximately 2000m. The GL was widely distributed in the east of the Yunnan, which had an average elevation gradient of almost 1800 m, with more than 70% at elevation gradients lower than 2000 m, approximately 20% between 2000 m and 3000 m and nearly 10% above 3000 m. WT and UB were located below elevation gradients of 2000 m, with the average elevation gradient up to 1700m. WT and UB, distributed in areas with gentle terrain and convenient locations, were the land cover types seriously impacted by human activities. UUL, the highest land cover type, was mainly spread above the elevation gradient of 4100 m. Only 17% of UUL was distributed below 4,000 m.

From 2001 to 2010, there were different decreases in the average elevation gradients of CL, WL and GL, the largest decline of average elevation gradients of land use type was UUL from 4100 m to 3750 m. However, there was a very small increase in the average elevation gradients of UB. Above 4000m, there were fewer changes to all land cover types because of few human activities in the high elevation gradient areas of the Yunnan.

The distribution of land cover types along with their slopes were summarized in Table 4. From the table, most of the land cover types under a certain slope had no significant changes with the passage of time. The average slope of the different land cover types from the lowest to the highest were WT, UB, CL, GL, WL and UUL. WT and UB were located in the zone with an average 2°, and only 13% of the area was located in a zone with a slope exceeding 6°. The average slopes of CL, WL and GL are approximately 6°. Almost 60% of CL as well as GL were distributed in zones with slopes lower than 6°, and 45% of WL was in zones with slopes below 6° as well as between 6° and 15°. UUL was the land cover type with the highest average slope, exceeding 11°, and approximately 39% and 36% of UUL in 2001 were located below 6° and 6°-15°, respectively.

Table 4. Slope gradient changes for different land cover types in Yunnan.

land cover	Average slope/			Area percentage/%											
				slope<6 °			6-15 °			15-25 °			slope>25 °		
	200	201	Δ	200	201	Δ	200	201	Δ	200	201	Δ	200	201	Δ
	1	0		1	0		1	0		1	0		1	0	
CL	5.76	5.2	-0.4	62.6	64.9	2.28	32.1	30.1	-2.0	4.9	4.7	-0.1	0.2	0.1	-0.0
		7	9	9	7		9	1	8	2	5	7	0	7	3

WL	7.57	7.6 3	0.0 6	46.7 2	45.5 6	-1.1 7	43.9 6	44.9 4	0.98	8.7 2	8.9 0	0.1 8	0.6 0	0.6 1	0.0 0
GL	6.09	5.9 1	-0.1 8	59.6 4	61.7 5	2.11	33.7 8	32.0 7	-1.7 2	6.1 2	5.7 0	-0.4 2	0.4 6	0.4 8	0.0 3
WT	2.10	2.2 9	0.1 9	86.7 9	86.9 7	0.18	10.6 7	11.1 8	0.51	2.3 7	1.6 1	-0.7 6	0.1 7	0.2 4	0.0 7
UB	2.50	2.5 8	0.0 8	87.6 3	87.6 4	0.01	11.5 9	11.5 8	-0.0 1	0.7 4	0.7 4	0.0 0	0.0 3	0.0 3	0.0 0
UUL	11.1 5	9.8 0	-1.3 5	38.8 4	27.1 6	-11. 7	35.7 1	38.2 7	2.56	18. 30	27. 8	9.4 7	7.1 4	6.7 9	-0.3 5

There were average slope decreases for most land cover types from 2001 to 2010, including CL, GL and UUL, and there were also small slope increases among the other types of land cover. The average slope of UUL dropped considerably, from 11.15° to 9.8°. Interestingly, the percentage of UUL in flatter areas (<6°) decrease and steep areas (15°-25°) increase. This finding implied that UUL was moving from flatter areas to steep areas.

3.3. Analysis of Landscape

Landscape configuration metrics were calculated using FRAGSTATS software based on the reclassified land-use map [23]. According to the characteristics of the landscape metrics, we found that the selected metrics had an ecological significance that described the characteristics of the landscape heterogeneity for operations. Results were shown in Table 5 and Table 6.

Table 5. The landscape patch types in Yunnan

	CA (ha)	PLAND	LPI(%)	PAFRAC	NP	PD	COHESION(%)
2001							
CL	5157675	13.4198	0.3812	1.5864	29253	0.0761	90.5247
WL	21975725	57.179	45.4179	1.5783	16727	0.0435	99.884
GL	10857475	28.2502	8.5471	1.6211	33267	0.0866	98.9083
WT	117475	0.3057	0.067	1.3844	758	0.002	85.4347
UB	301725	0.7851	0.0946	1.4667	1723	0.0045	81.2872
UUL	23150	0.0602	0.0104	1.4883	281	0.0007	69.4345
2010							
CL	5940425	15.4565	1.3859	1.5669	25679	0.0668	95.433
WL	22650375	58.9344	45.7657	1.5323	15193	0.0395	99.8725
GL	9399525	24.4568	7.8123	1.607	29044	0.0756	98.7974
WT	124800	0.3247	0.0729	1.4135	603	0.0016	87.8
UB	301800	0.7853	0.0947	1.4661	1723	0.0045	81.2238
UUL	16300	0.0424	0.0038	1.4694	167	0.0004	68.1645

CA: Class area. PLAND: Percentage of landscape. NP: Number of patches. PD: Patch density. LPI: Largest patch index. ED: Edge density. PAFRAC: Perimeter-area fractal dimension. COHESION: Patch cohesion index.

Table 6. Comparison of landscape metrics at the landscape level in Yunnan.

	TA (ha)	LPI	Area_ MN	SHAPE _AM	NP	PD	ENN_ MN	CON TAG	COHE SION	SPL IT	SHD I
2001	38433	45.4	468.65		820	0.2	1336.7				
	225	2		68.14	09	1	0	49.95	99.63	4.67	1.00
2010	38433	45.7	530.78		724	0.1	1377.8				
	225	7		52.96	09	9	8	51.80	99.59	4.61	1.00
											5

TA: Total area. NP: Number of patches. Area_MN: Mean patch area. PD: Patch density. LPI: Largest patch index. SHAPE_AM: Area-weighted mean shape index. ENN_MN: Mean Euclidean nearest neighbor distance. CONTAG: Contagion. COHESION: Patch cohesion index. SPLIT: Splitting index. SHDI: Shannon's diversity index.

At the class level, the NP and PD of all land cover types had a decreasing trend over the past 10 years, which showed that the fragmentary of these types dropped. According to LPI, WL represented the highest concentration of land use types, with an LPI reaching 45%. GL are the second concentration, and the other four types were found in very low. The LPI of CL increased significantly from 0.381 in 2001 to 1.386 in 2010, which reflected the fact that the distribution of CL in the Yunnan was more fragmentary in the early of 2000s. It should be noted that all PAFRAC of land cover types were at approximately 1.5, which indicated that the patch shape of this region was complex, thus human activities were relatively obvious and we should reduce the impact of human activities throughout the entire region.

The COHESION can measure the physical connectedness of the corresponding patch type. Different types of ecological landscapes have quite different degrees of aggregation. The aggregation of CL, WL and GL were higher than 90%, with efficient material and smooth energy flow. Over the past 10 years, the degrees of aggregation were unapparent, within the fluctuation range of $\pm 5\%$. In addition to CL, the fluctuation of aggregation in the rest of the landscape surface features was low. The COHESION of CL experienced growth from 90.5% in 2001 to 95.4% in 2010, indicating that the connection of CL improved.

At the landscape level, compared with 2001, NP in 2010 decreased from 82009 to 72409, and Area_MN expanded by approximately 62 ha, showed that many original patches joined together larger ones. The value of SHAPE_AM was declined from 68.14 in 2001 to 52.96 in 2010, which showed the shape of patch become more complex and irregular. SHDI changed from 1.007 in 2001 to 1.005 in 2010, which indicated that the landscape heterogeneity was decreasing slightly. During the 10 years, landscape fragmentation clearly dropped, the connection of landscape patches increased, and land cover gradually moved to the direction of stabilization and homogenization under the influence of human activities in the study area.

3.4. Analysis of driving factors

Land use change caused by human activities is the main cause of global environmental changes, and it is also the main factor of regional land use change. Differences of natural conditions determine the basic pattern of land use, while the conflicts between population and land accelerate the speed and extent of land use change. As well, traditional minority national customs, agricultural production mode and farming method can contribute to regional spatial heterogeneity of land use. Furthermore, under the impact of the market economy, seeking to maximize land use interest such as timber exploitation, agriculture planting, etc., is the direct cause of regional land use changes frequently. In addition, policy implementation has contributed to the change of land cover. The Yunnan is one of the provinces in the implementation of the Western Development Strategy that began in 2000, and its land cover has experienced changes influenced largely by the driving policy forces over the past 10 years. For example, the increase of WL areas indicates that the implementation of reforestation and afforestation of barren hills achieved some success as well as the promotion of sustainable economic development of Yunnan forestry.

Overall, its geographical features with more mountain less-flat plains determines the conflict between the growing demand for land and the limited supply that will exist for a long time with the development of urbanization and industrialization. To solve the land conflict of the Yunnan, the idea of constructing Mountainous Town was developed in 2011 and received a great deal of attention [10]. This idea suggested a slope-stratified and gradient -exploited land use pattern. The main areas of the Yunnan construction of Mountainous Town is located on the hilly slope land with slopes from 8° to 25° , with a total area of approximately 11570 km^2 , especially on barren hills and slopes unable to be afforested. This area can provide a broad space for the construction of Mountainous Town in Yunnan. So the scientific implementation of Mountainous Town policy will lead to major changes in the land cover pattern in Yunnan.

4. Conclusions

The quantitative evaluation of the land use dynamics in the Yunnan were developed from MODIS dataset from 2001 to 2010 and coupled with GIS analyses. The results showed that the regional change of land use structure in the area took on a type of regular pattern. Mutual transformations between the three types of land cover, WL, CL and GL, changed relatively dramatically, total 30 % of land cover area changing during the study period. In quantity, the most obvious land use changes were the increases of CL and the decrease of GL. By percentage, the most rapidly changing area occurred in UUL with the annual variation of 3.29 %.

Different land use types indicated disparate distribution and variation characteristics related to elevations and slopes. The average elevation gradient of different land cover types from the highest to the lowest was UUL, WL, GL, WT, UB and CL. Bare land was distributed in the highest and steepest areas, and CL was distributed in the gentle sloping valleys below 1700 m of the region. There were small changes in the average elevation for CL, WL, GL, WT and UB from 2001 to 2010. The most obvious decline in elevation happened for UUL, particularly in the range between 3,000 and 4,000 m. With the passage of time, most of the land cover types under a certain slope had no significant changes. The average slope of dropped from 11.15° to 9.8° , which mostly occurred in the zone below 6° .

On the basis of landscape metrics analysis, the results show stabilization and homogenization will be the direction of land cover structure in the future in Yunnan region. The regional differences of land

use structure in the area are strongly influenced by such factors as the geographical position, physiognomic situation, level of economic development and land use policy. The internal mechanisms of land use changes in Yunnan should be detected in the future research.

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