Spatio-temporal change analysis of land cover in Xichang City based on RS and GIS

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Abstract. The temporal and spatial change of land cover in Xichang City from 2002 to 2018 was analyzed in this paper. The current land cover maps of three different years were extracted based on the 2002, 2010 and 2018 Landsat remote sensing images, and the transfer Matrix model was utilized to analyze the transformation among types of land. The results showed that from 2002 to 2018, the area of cultivated land and construction land in Xichang increased by 20.26% and 191.71% respectively, while the areas of forest land, unused land, grassland and water decreased by 9.36%, 83.27%, 4.48% and 10.45%, respectively. In terms of spatial pattern, the regions with obvious changes are mainly located around the Anning River Valley and Qionghai Lake. The construction land increased significantly, mainly along the Beijing-Kunming expressway to the north of the new urban area and the cultivated land distribution increased slightly on the slope of some low mountain fallow land. Land cover conversion is quite frequent between cultivated land, forestland and grassland. This study can provide a scientific basis for the sustainable utilization of land resources and ecological construction in Xichang city.

1. Introduction
Land cover change has a significant impact on environmental change and terrestrial ecosystem, reflecting the complexity of internal structure and function of land use [1]. It is more intuitionistic and concrete to analyze the change of land cover from the angle of the whole pattern in space and the change process in time. Luo Geping and others analyzed the land cover change process in the middle and lower reaches of Yili River by using remote sensing image data, and predicted the future change trend according to the change characteristics[2]. Wang zongming and others quantitatively studied the dynamic change of land cover in Sanjiang plain by combining multi-phase remote sensing data with GIS spatial analysis[3]. In the study on dynamic change of land cover, RS and GIS are combined to truly, objectively and accurately understand the change of land cover in the region. In recent years, with the economic development and the influx of population, Xichang city has been expanding. The increase of population and the change of lifestyle will inevitably change the structure of land use and affect the ecological environment[4]. The study on the dynamic change characteristics and trends of land cover in Xichang City can provide reference for optimizing land use structure, to better coordinate the relationship between people and land and to cope with a series of ecological and environmental problems caused by the increase of population, and also provide a scientific basis for the sustainable development of regional land use.
2. Study area
Located in the southwest of Sichuan Province, Xichang City is located in the second largest plain of Sichuan Province, the Anning Valley Plain [5], with a total area of about 2,651 km$^2$ and a population of more than 690 thousand. The whole area is dominated by mountains, with an elevation of more than 1,500 m and valley plains running through the middle and low and high mountains distributed on both sides of the valley. The special valley high mountain landform and the abundant light and heat resources have formed the unique land use structure in this region. Human activities are mainly concentrated in the valley area and the piedmont fan plain on both sides of the valley. Most of the construction land is distributed in this area, and it is also the most concentrated area of cultivated land. On the lower slopes on both sides of the river valley, cultivated land or grassland formed by abandoned farmland is distributed, while in the higher areas, due to the restrictions of factors such as altitude, topography and transportation, human activities are less, and large areas of woodland and alpine grassland are distributed [6].

3. Data acquisition and processing methods

3.1. Data acquisition
In order to meet the image requirements of remote sensing data processing, and based on the actual situation of land use in Xichang for long period, three remote sensing images of Xichang City at different time periods are chosen as the basic data: Landsat-5TM (p130r41), Landsat-5TM (p130r41) and Landsat-8OLI (p130r41) in February 2002, March 2010 and February 2018 [7,8].

3.2. Image processing methods
In order to make the composite image easy to identify, bands RGB4, 3 and 2 of TM image and bands RGB5, 4 and 3 of OLI image are selected as the band combinations of the standard false color composite image [9,10]. According to the combination of field observation and Google image, the land use types in the research area are divided into 6 categories: cultivated land, forest land, grassland, water body, unused land and construction land. The accuracy of the three land use classification is evaluated [11], and the classification confusion Matrix and Kappa Coefficient are calculated. The results show that in 2002 (Figure 1a), 2010 (Figure 1b) and 2018 (Figure 1c), the accuracy is 98.51%, 98.34% and 97.66%, respectively, which are greater than 95%, and the Kappa coefficient is 0.98, 0.97 and 0.96, respectively, which are all higher than 0.9, and all satisfy the requirements of discrimination accuracy.

![Figure 1](image)

Figure 1. Land use status map of Xichang City. (a)2002;(b) 2010;(c)2018.

3.3. Transfer matrix model
The land use transfer matrix is a quantitative mutual transformation of quantity and direction between one land use type and other land use types, and the transformation and direction of transfer between land use types can be reflected [12]. The land use transfer matrix is established in ArcGIS, and the information of land class transformation is extracted on the basis of spatial superposition analysis. The formula of land use transfer matrix is:
In the formula: \( S_{ij} \) is the area of the land transformation from type \( i \) into type \( j \) during the research period; \( i \) is the type of land in the first period; \( j \) is the type of land in the second period; \( n \) is the number of land use types [13].

4. Results

4.1. Quantitative change analysis

Figure shows the current status of land use in Xichang city. The land cover classification results are statistically analyzed to obtain the change table of land type and area in Xichang in 2002, 2010 and 2018. (See Table 1)

**Table 1. Land type area and rate change of Xichang City in 2002, 2010 and 2018.**

| Year | Forestland | Unused Land | Grassland | Cultivated Land | Construction Land | Water Body |
|------|-------------|-------------|-----------|-----------------|-------------------|------------|
|      | Area \( \text{km}^2 \) | Rate % | Area \( \text{km}^2 \) | Rate % | Area \( \text{km}^2 \) | Rate % | Area \( \text{km}^2 \) | Rate % |
| 2002 | 1035.83     | 38.93      | 76.55     | 2.88           | 963.12            | 36.19     | 493.68       | 18.55     | 56.88       | 2.14     |
| 2010 | 933.35      | 35.09      | 17.00     | 0.64           | 941.12            | 35.39     | 560.04       | 21.06     | 161.82      | 6.08     |
| 2018 | 938.87      | 35.28      | 12.81     | 0.48           | 920.00            | 34.57     | 593.71       | 22.31     | 164.24      | 6.17     |

In terms of land cover structure, the land use in 2002 was mainly forest land, grassland and cultivated land, and the three types of land accounted for 38.93%, 36.19% and 18.55% of the total area respectively (Table 1). The land use structure in 2010 was similar to that in 2002, with the main land use types unchanged. Among them, 35.09% of the total land area was forest land, 35.39% was grassland, and 21.06% was cultivated land. Since 2005, the proportion of cultivated land had been further increased due to ecological conversion and land reclamation, accounting for 22.31% of the total area in 2018. By 2018, the proportion of forested land and grassland had declined due to deliberate deforestation. The development of economic trees led to periodic loss and forest fire, and the two main types of forest land and grassland only accounted for 69.86% of the total land area. With the development of urbanization, the proportion of construction land kept rising, and from 2002 to 2010 to 2018, it accounted for 2.14%, 6.08% and 6.17% of the total area respectively.

With the continuous development of land resources, from 2002 to 2018, the area of forestland decreased by 96.96\( \text{km}^2 \) and 9.36%, the area of unused land decreased by 63.74\( \text{km}^2 \) and 83.27%, the area of grassland decreased by 43.12\( \text{km}^2 \) and 4.48%, and the area of cultivated land increased by 100.03\( \text{km}^2 \) and 16.85%, the area of construction land increased by 107.36\( \text{km}^2 \) and 191.71%, and the area of water decreased by 3.65\( \text{km}^2 \) and 10.45%. In terms of the degree of change, the change of construction land was the most significant, which had increased by nearly twice in 16 years. The amount of cultivated land had been increasing steadily; the unused land had been reduced at a faster rate, while the decrease of forest land, grassland and water body was relatively small.

4.2. Spatial change analysis

The land types are changing dynamically in space. Among them, the unused land is scattered and relatively small in the low mountains west of the Anning River, gradually disappearing in the process of afforestation and grass planting (Figure 1). The water body of Xichang is mainly located in the Anning River Basin and the Qionghai Lake area. The water body reduction is mainly concentrated around the Qionghai Lake wetland, which is mainly caused by the development of Qionghai lake's...
tourism, recreation and vacation. However, the overall spatial pattern of forest land, grassland, arable land and construction land is prominent, which changes obviously with time to some extent.

4.2.1. The Change of Forestland Distribution

Figure 2. The distribution of forest land in Xichang City. (a) 2002; (b) 2010; (c) 2018.
As the main land use type in Xichang City, forestland is mainly distributed in Yak Mountain in the west of Xichang and Luoji Mountain in the southeast of Xichang. Due to the high altitude, it is less affected by human activities and is mostly natural vegetation forest. From 2002 to 2010, due to human destruction, the exploitation of economic forest trees resulted in the degradation of some forest lands, and the forest lands in the southwest of Mopan Mountain and Lushan Mountain scenic area showed a significant trend of decline (Figure 2a and 2b). By 2018, thanks to the policy of returning farmland to forest and the implementation of the natural forest protection project, the forestland in the mountainous areas in southwest China and the Lushan scenic spot has been restored (Figure 2c).

4.2.2. The Change of Grassland Distribution

Figure 3. The distribution of grassland in Xichang City. (a) 2002; (b) 2010; (c) 2018.
Most of the grassland in Xichang is located in the lower mountains and abandoned slopes on both sides of the Anning River Valley, and it is distributed in interphase with the forestland, with a large amount (Figure 3). From 2002 to 2018, the spatial decrease of grassland was mainly concentrated in the northwest and southwest low-mountain areas, and the reasons mainly included the artificial destruction and the reclamation of some abandoned grassland.

4.2.3. The change of cultivated land distribution.
The cultivated land in Xichang is mainly distributed in the Anning Valley Plain and Qionghai Lake Basin. It is still distributed sporadically in the low mountain areas, where the traditional methods of shifting cultivation, rotation and burning still exist (Figure 4). From 2002 to 2018, with the pressure of population growth, Xichang, as an important food production area, steadily increased the cultivated land on the premise of balanced land supply. Not only in the Qionghai Basin and the Anning River valley plains, but also in the low mountain areas in the West and the mountainous areas in the southwest, due to the implementation of land renovation projects such as the development and reclamation of land destroyed by low slopes and natural disasters, cultivated land resources have also been supplemented.
4.2.4. The change of construction land distribution

Most of the construction land in Xichang City is distributed in the urban area in the north of Qionghai Lake, and some of it is distributed in the form of urban settlements on both sides of the Anning River (Figure 5). In recent years, because of the improvement of the urbanization level, the optimization and adjustment of the industrial structure, the change of human activities and the construction of a large number of infrastructure facilities, the construction land has changed significantly in space from 2002 to 2018. The city's key development areas are concentrated along the Yapan expressway and the Chengdu-Kunming railway, forming a pattern of development mainly in the north-south direction, supplemented by appropriate development in the east and west. The increase of construction land in northern new town is especially outstanding, and the expansion of construction land in northern industrial park and northern Qionghai is most significant.

4.3. Interclass Transformation Analysis

Table 2. The area transfer matrices of land use type from 2002 to 2010.

| Items /km²  | Forestland | Water Body | Unused Land | Grassland | Cultivated Land | Construction Land | Total   |
|-------------|------------|------------|-------------|-----------|-----------------|------------------|---------|
| 2002        | 839.00     | 2.39       | 84.88       | 6.49      | 0.33            | 933.09           | 2010    |
| 2010        | 137.89     | 0.07       | 57.02       | 688.69    | 51.25           | 940.82           |         |
In the process of dynamic change of land cover in Xichang City, there exists the phenomenon of transferring in and out among different land use types. The transfer matrices of land cover from 2002 to 2010, from 2010 to 2018 and from 2002 to 2018 are shown in Table 2, Table 3 and Table 4 respectively.

### Table 3. The area transfer matrices of land use type from 2010 to 2018.

| Items /km² | 2010 | | | | | | Total |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | Forestland | Water Body | Unused Land | Grassland | Cultivated Land | Construction Land | |
| Forestland | 765.12 | 3.59 | 0.34 | 122.72 | 25.12 | 21.36 | 938.26 |
| Water Body | 26.70 | 0.00 | 0.05 | 0.59 | 3.66 | 31.01 |
| Unused Land | 0.00 | 0.00 | 0.28 | 10.78 | 1.59 | 0.15 | 12.80 |
| Grassland | 86.90 | 4.17 | 11.72 | 684.07 | 105.75 | 26.75 | 919.36 |
| Cultivated Land | 80.85 | 2.32 | 4.58 | 115.76 | 338.91 | 50.91 | 593.34 |
| Construction Land | 0.13 | 9.37 | 0.08 | 7.44 | 87.92 | 58.92 | 163.86 |
| Total | 933.00 | 46.16 | 17.00 | 940.82 | 559.89 | 161.76 | 2658.63 |

### Table 4. The area transfer matrices of land use type from 2002 to 2018.

| Items /km² | 2002 | | | | | | Total |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | Forestland | Water Body | Unused Land | Grassland | Cultivated Land | Construction Land | |
| Forestland | 845.54 | 0.22 | 0.40 | 80.07 | 10.93 | 1.71 | 938.86 |
| Water Body | 0.14 | 28.66 | 0.01 | 0.15 | 1.96 | 0.35 | 31.27 |
| Unused Land | 0.05 | 0.00 | 7.45 | 4.81 | 0.50 | 0.00 | 12.81 |
| Grassland | 110.28 | 0.16 | 50.56 | 717.24 | 31.34 | 10.43 | 920.00 |
| Cultivated Land | 79.21 | 0.93 | 17.37 | 150.74 | 340.45 | 5.01 | 593.71 |
| Construction Land | 0.52 | 4.95 | 0.77 | 10.1 | 108.51 | 39.38 | 164.24 |
| Total | 1035.74 | 34.92 | 76.55 | 963.12 | 493.68 | 56.88 | 2660.89 |

#### 4.3.1. Transformation of forestland. From 2002 to 2010, the forestland was transferred in 94.09 km² and out 196.09 km². The grassland was transferred in 84.88 km²; the unused land and cultivated land were transferred in 2.39 km² and 6.69 km² respectively. Grassland was the main area to be transferred out of, and 137.89 km² of forestland was converted into grassland. The destruction behavior such as indiscriminate cutting and logging was the direct reason that led to the degradation of part of forestland into grassland.

From 2010 to 2018, the forestland was transferred in 173.14 km² and out 176.88 km². It was dominated by the transfer of grassland, with the transferred area of 122.72 km², accounting for 70.9% of the whole transfer. Grassland and arable land accounted for 49.1% and 45.7% of the total.

From 2002 to 2018, the total conversion of forest land was as follows: Forestland was transferred in from other types of land to 93.32 km² and transferred out 190.2 km². Grassland was the main conversion type, and the area of grassland conversion was 80.07 km², and the area of forestland conversion to grassland was 110.28 km².
4.3.2. Transformation of water body. From 2002 to 2010, the water body was transferred in 17.81 km² and transferred out 5.94 km². Forestland was transferred in 3.29 km², grassland to 4.02 km², arable land to 6.44 km², construction land to 3.86 km², and unused land to 0.02 km². The water body was mainly transferred to construction land and cultivated land, with the area of 4.35 km² and 1.52 km² respectively.

From 2010 to 2018, the water body was transferred in 4.31 km² and transferred out 19.46 km², and transferring out was more than transferring in. The reasons mainly lied in the harnessing of the Anning River Basin and the siting up of the eastern shore of the Qionghai Lake and the building of farmland around it. In recent years, the local tourism industry and the tourist resources of the Qionghai Lake had been vigorously developed. Moreover, entertainment, catering, leisure and other tourism facilities occupied part of the water body around Qionghai Lake. Among them, 9.37 km² was transferred out for construction land.

From 2002 to 2018, the total transformation of water body was as follows: water body transferred from other types of land to 2.61 km² and out to 6.26 km², with the most obvious transformation between water body and construction land.

4.3.3. Transformation of unused land. From 2002 to 2010, the unused land was transferred in far more than transferred out, with the transfer in only 14.96 km² and the transfer out reaching 74.46 km². Of these, 76.58% were converted to grassland and 15.94% to cultivated land.

From 2010 to 2018, the unused land was transferred in 12.52 km², while the unused land was transferred out 16.72 km². The grassland was transferred in 10.98 km², and the cultivated land was transferred in 1.59 km². Most of the transferring out was grassland, with an area of 11.72 km².

From 2002 to 2018, the total transformation of unused land was as follows: The unused land was transferred from other land types to 5.36 km², and then transferred out 69.1 km², mainly to the grassland planted on the low mountain slope, and converted to grassland with an area of 50.56 km².

4.3.4. Transformation of grassland. From 2002 to 2010, the grassland was transferred into 252.14 km² and out of 273.74 km². Among them, the transferred situations included: forestland transferred to 137.89 km², unused land transferred to 57.02 km², cultivated land transferred to 51.25 km², and a small amount of construction land transferred to 5.91 km². Most of them were cultivated land, which was 147.29 km². The growth of population increased the demand for food, leading to the decrease of wasteland and the increase of cultivated land. 84.88 km² was converted into forestland, 4.02 km² into water body, 12.09 km² into unused land and 25.46 km² into construction land.

From 2010 to 2018, the grassland was transferred into 235.29 km² and out of 256.75 km². Due to the implementation of the policy of returning farmland to forest and grassland, the conversion situation was mainly the conversion of cultivated land, with an area of 105.75 km². The transfer was mainly to forestland, and 122.72 km² was transferred to forestland.

From 2002 to 2018, the total transformation of grassland was as follows: the grassland was transferred in 202.76 km² from other land types, and transferred out 245.88 km² to other land types. Among them, forest land was mainly transferred into, and transferred into 110.28 km².

4.3.5. Transformation of cultivated land. From 2002 to 2010, the cultivated land was transferred into 212.53 km² and out of 146.1 km². Among them, the transfer of grassland was the main one, with the transferred area of 147.29 km², accounting for 69.3% of the transferred farmland. Population growth has led to a serious problem of pressure on cultivated land. In order to reduce the pressure on cultivated land, some wild grassland and forest land have been reclaimed for cultivated land. The transferring out was mainly based on construction land, with an area of about 79.67 km², accounting for 54.53% of the transfer out. Some of them were transferred to grassland, forestland, water body and unused land, with an area of 51.25 km², 6.49 km², 6.44 km² and 2.25 km², respectively.

From 2010 to 2018, farmland was transferred into 254.43 km² and out 220.98 km². The large shift in arable land reflected the sharp rise in food demand as a result of rapid population and economic
growth. Among them, 115.76 km$^2$ grasslands were transferred into, accounting for 45.5% of the transferred amount. The main transferring out was to grassland, with an area of about 105.75 km$^2$. 87.92 km$^2$ cultivated lands were also transferred to construction land, and 25.12 km$^2$ transferred to forest land.

From 2002 to 2018, the cultivated land was transferred into 253.26 km$^2$ and out of 153.23 km$^2$. Among them, forest land and grassland were the main transfer-in types, which were 79.21 km$^2$ and 150.74 km$^2$ respectively. Construction land and grassland were the main transfer-out types, transferred out of 108.51 km$^2$ and 31.34 km$^2$ respectively.

4.3.6. Transformation of construction land. From 2002 to 2010, the amount of construction land transferred in was 5 times that of the amount transferred out. The area transferred in was 130.18 km$^2$, while the amount transferred out was only 24.48 km$^2$.

From 2010 to 2018, construction land was transferred into 104.94 km$^2$ and out of 102.84 km$^2$, with a similar amount transferred in and out.

From 2002 to 2018, the total transformation of construction land was as follows: construction land was transferred from other land types into 124.86 km$^2$, and transferred out of 17.5 km$^2$. The cultivated land had a great relationship with its transfer-in, which accounted for 86.91% of the total amount and covered an area of 108.51 km$^2$.

5. Discussion and conclusions
From 2002 to 2018, the increase and decrease of land use types in Xichang were distinguished. The areas of forest land, unused land, grassland and water were reduced by 9.36%, 83.27%, 4.48% and 10.45%, respectively. The areas of cultivated land and construction land were increased, and the cultivated land was increased by 20.26%, among which the construction land increased by nearly 2 times. However, in the process of change, forest land and grassland were always the main land types.

In the spatial pattern, the key change areas were in the Anning River Valley and around the Qionghai Lake. The increase and decrease of forestland were mainly concentrated in the western high altitude area and the southeast area. The scope of construction land had expanded significantly, mainly to the new urban areas in the north, which was influenced mostly by human factors such as the growth of population and the regulation of city development. Cultivated land had increased in the alluvial fan of river valleys and the gentle slope areas of low mountains. Grasslands were widely distributed and relatively scattered in the mountains at low and middle altitudes.

The transformation among land cover types was quite obvious, and the transformation between forest land, cultivated land and grassland was relatively frequent. The transferring objects of forest land were all grassland; the transferring-out area of cultivated land was less than the transferring-in area, and the amount of transferring-in was larger, and the forest land and grassland were the main types of transferring-in. The main source of grassland was forest land, which mainly transferred into cultivated land.

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