

# The study on the spatial-temporal changes of land use pattern in eastern Sichuan basin based on RS/GIS

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**Abstract:** Eastern Sichuan Basin is one of the areas sensitive to global climate change. Due to impacts from human disturbance, the farmland in the study area has been degrading, and the desertification of land has been expanding rapidly. Based on the data of Landsat TM/ETM image in 1990, 1995, 2000, 2005 and 2010, this thesis analysed the spatial characteristics and dynamic trends of land use pattern in eastern Sichuan basin using software for remote sense and geographical information system. The driving factors of land-use change in study area were also discussed. The results indicated that: (i) the area of farmland has significantly decreased because of degradation and conversion from grassland into building land; (ii) farmland patches have changed into fragmented and isolated ones; (iii) the main landscapes in study area, are farmland and forests; (iv) land-use change is significantly associated with the human activities. This study provides a strong theoretical and technical basis for the policy-making of environmental protection and management in Eastern Sichuan Basin of Sichuan Province in china.

## 1. Introduction

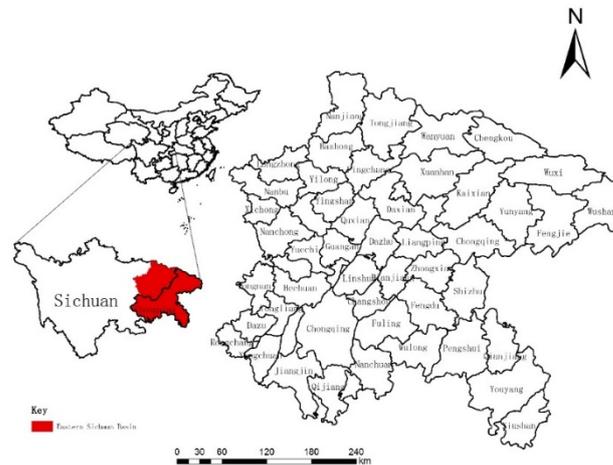
Land-use change is an important component and driving factor of land ecosystem change, and it has vital impact on global climate change and sustainable development<sup>[1-2]</sup>. Recent research in landscape ecology has sought to define the spatial-temporal change of landscape structure. Spatial technology tools such as geographic information systems (GIS) and remote sensing have given ecologists unprecedented capacity to quantify landscape structure, spatial heterogeneity, and landscape change<sup>[3-5]</sup>. The change of land-use pattern influences the biodiversity of terrestrial ecosystem, population dynamics of plants and animals as well as primary productivity<sup>[6-9]</sup>. In addition, land-use change even affects the global biogeochemical cycle and the content of greenhouse gases in the atmosphere. The study on the trend of land use change and environmental effect has become the main research contents of the LUCC<sup>[10-12]</sup>. Besides, the quantitative analysis of driving factors about land use change is equally important<sup>[13]</sup>.

Eastern Sichuan basin is an important water conservation area of Yangtze River. In recent years, the land use pattern of eastern Sichuan basin has been changed by human disturbance and the deterioration of natural conditions<sup>[14-16]</sup>. In this study, eastern Sichuan basin was selected as a case study area to conduct appropriate analysis for studying land use structural changes in the upper reaches of the Yangtze River Region. Then, Digital image processing techniques were used to obtain landscape classification maps in the years of 1990, 1995, 2000, 2005 and 2010. Based on the GIS and FRAGSTATS, landscape pattern indices were calculated, and the relationship between the landscape change and human disturbance was further analysed. The analysis results can give strong technical support for coordinating the eco-environmental protection and sustainable development in eastern Sichuan basin.



## 2. Study area and method

### 2.1. Study area

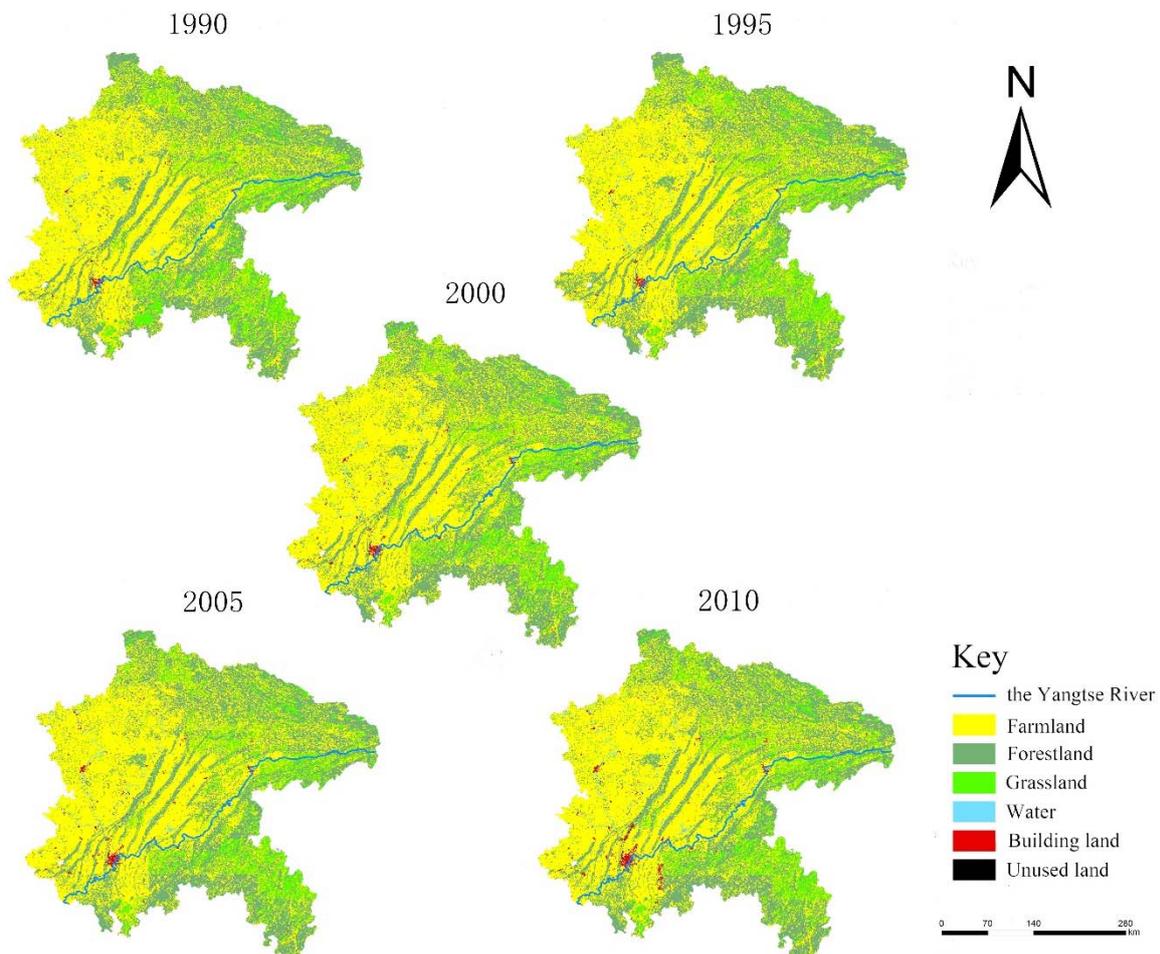


**Figure 1.** The location of eastern Sichuan basin prefecture.

Eastern Sichuan basin includes Chongqing, Guang'an, Dazhou, Bazhou and Nanchong city (fig.1). It is located between  $28^{\circ}10'$ — $32^{\circ}45'$ , and  $105^{\circ}11'$ — $110^{\circ}11'$ , with a total area of  $12.9 \times 10^4 \text{ km}^2$ . The average elevation is 685.5m. Eastern Sichuan basin belongs to the mid-subtropical China climate type, and it has typical warm and humid marine climate characteristics. The annual average temperature is about  $16 \sim 20^{\circ}\text{C}$ , and the annual precipitation is 1000~1300mm. Due to the complex terrain, landforms, and high heterogeneity of climate, vegetation types are very rich. There are nearly ten thousand kinds of plants in this area. Not only subtropical evergreen broadleaved forest, but also mixed evergreen and deciduous broadleaved forest can be seen in this area.

### 2.2. Methodology

To quantify land-use structure is the basis of the study of function and change of ecosystem. Firstly, the landscape types were divided into 6 categories: forest, grassland, farmland, water area, building and bare land (fig.2). Then the DEM, the slope map and the aspect map were produced. The landscape types of three periods were overlapped and the matrix of LUCC was obtained by using the spatial data overlay analysis. Furthermore, the spatial analysis module of ARCGIS and FRAGSTATS software were used to calculate the landscape pattern metrics <sup>[17]</sup>.



**Figure 2.** Land use type distribution maps of eastern Sichuan basin in different period.

### 3. Results and analyses

#### 3.1. Change characteristics of land use type in eastern Sichuan basin

During 1990 - 2010, the changes of land use types in the study area indicated the decrease of grassland and farmland and the rapid increase of building land. In terms of space scale, the farmland reduced 971.5 km<sup>2</sup> with an annual average of 48.6 km<sup>2</sup>. Forestland increased from 32.8% to 33.7% of entire lands during the study period, with 1165 km<sup>2</sup> of increased area. Meanwhile, the area of grassland was reduced to 1112 km<sup>2</sup> until 2010, a 7.8% decrease compared to that in 1990. The data also showed that the area of buildings accounted for 0.47% of the total area in 1990, and 1.0% in 2010.

The data of patch numbers indicated that the landscape patches have become considerable fragmentation during the study period (Tab.1). The number of patches has particularly increased, highlighting the forestland has broken into smaller parcels, with a total number of 2497 to 2664 patches. However, the number of farmland patches was just slightly increased from 2368 to 2393 (Tab.2). The patches shape of the whole lands was slightly regular in 2010 compared to that in 1990, value reducing from 1.2793 to 1.2684.

There are some reasons for these results. During the study period, the eastern Sichuan basin adjusted the land use structure and ensured the basic balance of cultivated land requisition and compensation. And the local government adopted an adaptation approach to increase the forest area, which mainly

adjust the species instead of increasing the area as the main direction of development. Reducing unused land to develop the land for construction. From 2005 to 2010, the increasing trend of environmental pollution and ecological damage basically got controlled. Land resources were effectively protected and the sustainable use of land can be guaranteed.

**Table 1.** Change of land use types in the eastern Sichuan basin from 1990 to 2010.

Land type	Year	Path density	Max PD	Fractal dimension	Shape index
Farmland	1990	0.0184	43.6293	1.0258	1.3039
	1995	0.0182	42.8217	1.0248	1.2826
	2000	0.0185	43.9120	1.0243	1.2770
	2005	0.0183	43.3356	1.0241	1.2732
	2010	0.0186	42.8523	1.0239	1.2712
Forestland	1990	0.0194	11.8403	1.0219	1.2678
	1995	0.0197	9.3884	1.0235	1.2685
	2000	0.0204	11.5817	1.0237	1.2688
	2005	0.0207	11.6567	1.0236	1.2669
	2010	0.0207	11.6759	1.0236	1.2663
Grassland	1990	0.0194	0.7079	1.0252	1.2898
	1995	0.0183	2.1657	1.0239	1.2709
	2000	0.0185	2.0624	1.0243	1.2757
	2005	0.0183	1.9079	1.0241	1.2727
	2010	0.0184	1.9249	1.0240	1.2707
Water	1990	0.0051	0.0379	1.0237	1.2676
	1995	0.0057	0.0201	1.0240	1.2706
	2000	0.0056	0.0363	1.0239	1.2687
	2005	0.0055	0.0363	1.0238	1.2675
	2010	0.0056	0.0549	1.0237	1.2667
Building land	1990	0.0026	0.0896	1.0245	1.2798
	1995	0.0027	0.0966	1.0244	1.2780
	2000	0.0028	0.1329	1.0241	1.2730
	2005	0.0030	0.1692	1.0240	1.2705
	2010	0.0034	0.2133	1.0239	1.2691
Unused land	1990	0.0002	0.0015	1.0237	1.2670
	1995	0.0003	0.0023	1.0244	1.2774
	2000	0.0002	0.0015	1.0239	1.2685
	2005	0.0002	0.0015	1.0237	1.2673
	2010	0.0002	0.0015	1.0237	1.2666

**Table 2.** Change of landscape pattern indices in the eastern Sichuan basin from 1990 to 2010.

Year	Patch density	Fractal dimension	Shape index	Diversity index
1990	0.065	1.0241	1.2793	1.0340
1995	0.065	1.0242	1.2747	1.0414
2000	0.066	1.0240	1.2720	1.0364
2005	0.0661	1.0239	1.2697	1.0409
2010	0.0669	1.0238	1.2684	1.0546

### *3.2. Landscape pattern dynamics in eastern Sichuan basin*

The general trend depicted by the landscape structure analysis is increase in landscape diversity, and decrease in shape index during the study period (Tab.2). The results showed that the shape index of farmlands was decreased and the fractal dimension index was reduced in 2010. Shape index of grasslands was slightly decreased from 1.2898 in 1990 to 1.2707 in 2010. While for forests, the fractal index value was 1.0219, 1.0235, 1.0237, 1.0236, and 1.0236 in 1990, 1995, 2000, 2005 and 2010 respectively. This variable may be owned to a large increase of human disturbance from an over-livestock, tourism and transportation during the last decades.

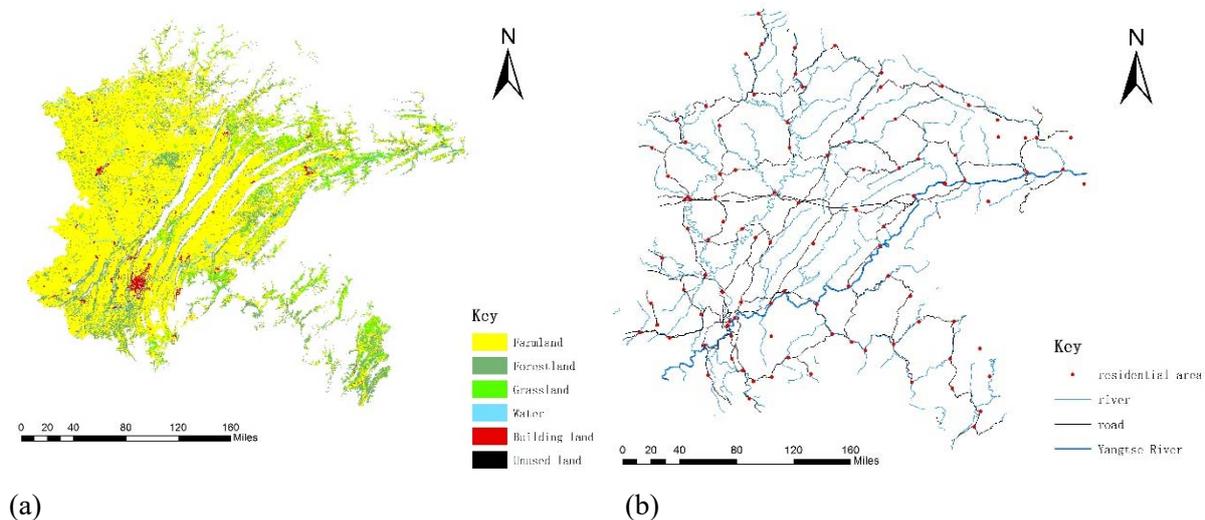
The fractal dimension index was used to analyse the change of landscape spatial distribution attributes. It can test whether the landscape patches are random distribution and will subsequently reflect the aggregation and separation of landscape patches. The result indicated that the distributions of various landscape types tend to the state of aggregation during the study period, showing a little change. Same situation happened for waters and farmlands, near a complete glomerate distribution, similar situation for the forest and bare lands. Though the fractal dimension index of grasslands is 1.5% for the variable rate, the grasslands still keep a stable aggregation. This uneven distribution pattern will result in unbalance of ecological functions for the grassland regions.

The residential area of Chongqing city, Nanchong city and Nanchuan city expanded significantly higher than other regions. By a transition matrix analysis, we know that total area of farmland land and grassland were reduced, and the number of forest was increased. Especially, the amount of transferred land between forest land and farmland was larger than other land use types, almost 34 thousand hectares. This situation may be closely related to the implementation of the Grain to Green Project.

### *3.3. The main driving factors of land use change in eastern Sichuan basin*

The decision-making for an optimum management should be based on various aspects, of human impacts, land use types, topography, etc. All these factors should be comprehensively taken into account before a new policy was established in order to reduce environmental loss. It has the characteristics of complicated terrain and obvious humid subtropical monsoon climate in Eastern Sichuan Basin. The differences of natural conditions determine the temporal and spatial heterogeneity of land cover pattern. The natural factors include elevation, slope, distance from river and road and so on. When the altitude below 600 meters(fig.3-a), the area would be occupied by the farmland, so the farmland's area takes more than 50% of the entire region. The concentrated areas of urban and rural residential land are basically distributed along rivers or roads (fig.3-b).

Secondly, the economic, population density and some other social factors also affect the land use change. The farmland in eastern Sichuan basin is more developed than other land types, so the proportion of artificial ecosystem is larger. But the artificial ecosystem is characterized by the single of structure. From the change of the shape index and fractal dimension, we can see that the farmland ecosystem tends to be homogenized. Therefore, the ecosystem ability of self-regulation is not strong, and lack of stability, so it can be more easily destroyed. But the agricultural ecosystem' yield is high, which can bring much more social benefits. It is also one of the important factors of ecosystem' s fragility and fragmentation. Although the government has increased the implementation of returning farmland to forests, but the proportion of cultivated land is still the largest. Besides, with the expansion of building area and degradation of grassland, the impact of human activities on the land-use pattern will be more and more significant.



**Figure 3.** (a) Land use types below 600 meters above sea level and (b) the relation between the distribution of settlements and the rivers and roads.

#### 4. Discussions

The main land use type in study area is farmland in study period. The number of farmland patches is increasing trend but the area is decreased. And the shape of patches tends to be single. the number of forestland is lager, but the areas of farmland and grassland are smaller. At the same time, with the industrialization and urbanization, the building land is increased. The reason may be the implementation of the policy of returning farmland to forests and strengthening ecological protection,

The distribution of land types in eastern Sichuan basin shows an obviously vertical zonality and horizontal zonality in space. the eastern Sichuan basin formed a complex topography, and the climate is diverse with different altitude. Generally, the temperature in the basin is higher than the marginal mountain areas, but the precipitation is less than the mountain areas. The majority farmland is in low altitude areas, the forestland and some grassland are in high altitude areas. The expansion of building land is similar in both space and time scales, and the building lands are basically distributed along rivers or roads.

The eastern Sichuan basin belongs to the important ecological barrier zone in the hilly area of upper middle reaches of the Yangtze river. This study acquired landscape structure information that is valuable in land use management. The types of datasets, statistical approach, mapping techniques, and spatial analysis used in this study could provide with appropriate information for assessment and planning of landscape pattern, and can also be used to support policy formulation pertaining to ecological conservation.

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