

Monitoring the Effects of the Grain to Green Projects Using Landscape Metrics: A Case Study in Eastern Sichuan, China

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Abstract. Eastern Sichuan is an important ecological barrier in the upper reaches of the Yangtze River. Based on 1990, 1995, 2000, 2005, 2010 and 2015 Landsat TM / ETM image data, the dynamics change of land use is analysed by using remote sensing and GIS software. The trend of change measures the effect of the Grain to Green Projects in the study area. The results show that farmland was the main type of land, and building land had the most dynamic degree during the period of studying. Since the implementation of the Grain to Green Projects in 2000, the area of farmland has decreased and the patches have been fragmented. The area of forestland has increased and the connectivity of patches has increased. The shape of grass types has tended to be regular. At the same time, the overall landscape diversity has increased and the spatial layout has become increasingly regularized. This study provides a theoretical support for policy-making of environmental protection and management in Eastern Sichuan Region of Sichuan Province.

1. Introduction

With the rapid development of the social economy, the urbanization rate has increased. Therefore, the relationship between human being and land has become increasingly tense^[1, 2], and the ecological environment has also been severely damaged. In order to improve the ecological environment, Chinese government implemented the Grain to Green Projects. The project was the first demonstration project to be carried out in Sichuan in 1999^[3]. The Grain to Green Projects can cause large-scale and changeable land-use change^[3,4], which will affect the environment. In recent years, domestic and foreign scholars have conducted a series of studies on the Grain to Green Projects^[5]. As an important ecological barrier in the upper reaches of the Yangtze River^[6], Eastern Sichuan relates to the ecological security closely in China. This paper selects Eastern Sichuan as a research area to analyse the effects of the Grain to Green Projects and provide strong technical support for the ecological environment protection and sustainable development.

2. Study area and method

2.1 Study area

Eastern Sichuan basin includes Chongqing, Guang'an, Dazhou, Bazhong and Nanchong city (fig.1). It is located between 28°10'—32°45' and 105°11'—110°11', with total area 12.9×10⁴ km². The average elevation of whole is 685.5 m. 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 16~20 °C, and the annual precipitation is 1000~1300 mm. 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 could be seen in this area.

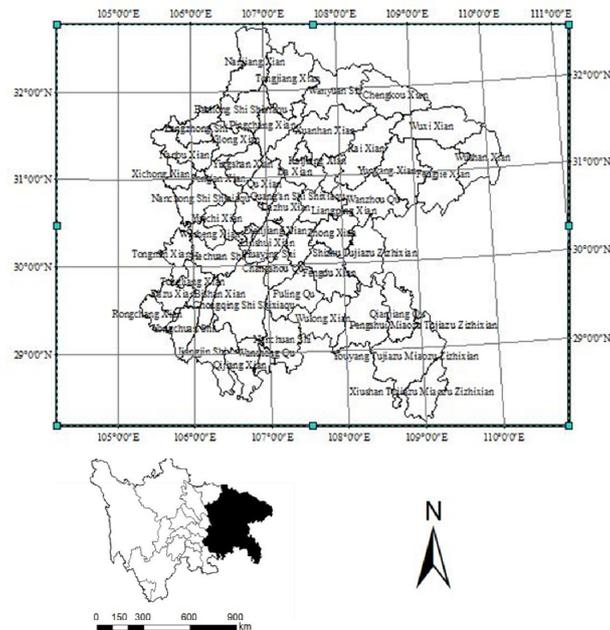


Fig. 1. The location of eastern Sichuan basin prefecture.

2.2 Methodology

Quantifying land-use types is a base for the study of landscape pattern change. The remote sensing imagery data of year 1990, 1995, 2000, 2005, 2010 and 2015 with 1:250000 topographic map, soil and plant thematic map were used to landscape types. The landscape was divided into 6 categories including farmland, forestland, grassland, water land, building land and unused land (fig.2). The landscape types of six 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 [7]. The dynamic degree of land use was an another indicator for assessing the regional differences.

Dynamic degree of single land use:

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

Degree of comprehensive land use:

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

U_a and U_b represent the area of a single land use type at beginning and end of the study period. LU_i represents the initial area of land use type i . ΔLU_{i-j} is the area of land use type i transforming to land use type j during the study period. T is the range of the study period.

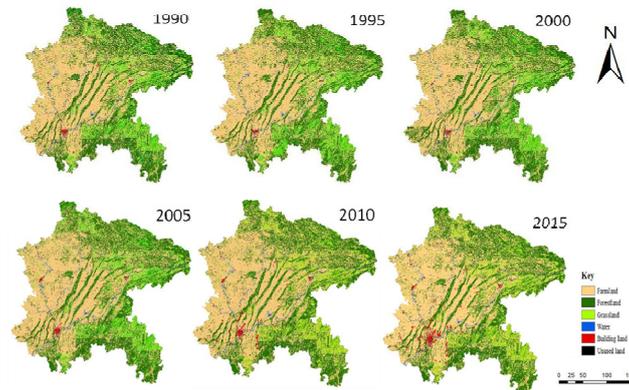


Fig.2. Land use type distribution maps of eastern Sichuan basin in different period.

3.Results and analysis

3.1 Dynamic Degree of Land Use Types

According to the dynamic degree of land-use, forestland, water land, and building land showed an increasing trend, and farmland, grassland, and unused land showed an opposite trend.

During the 25 years, the farmland area showed a decrease-increase-decrease pattern, and the forestland continued to increase. There was a significant turning point from 2000 to 2005. The area of farmland changed from increase to decrease after 2000. At the same time, the forestland increased, and during the inflection period, the dynamics of forestland increased significantly. Furthermore, although there was a negative change in the area of forestland between 2010 and 2015, it was much smaller than the reduced area of farmland. In short, the area of farmland decreased by 172,500 hectares, and forestland increased by 33,500 hectares in the period of study. This proves that the Grain to Green Projects has get a significant effect on returning farmland to forestland and substantially reduced the loss rate of forest since 2000.

Dynamic degree of comprehensive land use was the smallest during the period of the Grain to Green Projects, but the single dynamic degree of land use types varied greatly. This also shows the project not only pursues a reduction in the area of farmland and an increase in forestland, but also pays attention to the overall change in the overall landscape pattern for getting maximized benefits of the regional ecosystem.

Table 1. Dynamic degree (%) of land use types in Eastern Sichuan, 1990-2015.

Years		1990-1995	1995-2000	2000-2005
Dynamic degree of single land use	Farmland	-0.0026	0.0029	-0.0012
	Forestland	0.0031	0.0005	0.0028
	Grassland	0.0079	-0.0086	-0.0028
	Water land	0.0211	-0.0057	-0.0118
	Building land	0.0251	0.0411	0.0392
	Unused land	0.0286	-0.0200	-0.0017
Degree of comprehensive land use		0.0016	0.0014	0.0011

Years		2005-2010	2010-2015	1990-2015
Dynamic degree of single land use	Farmland	-0.0015	-0.0023	-0.0010
	Forestland	0.0005	-0.0002	0.0014
	Grassland	0.0009	-0.0008	-0.0007
	Water land	-0.0137	0.0043	0.0097
	Building land	0.0726	0.1281	0.1051
	Unused land	0	0.0061	-0.0011
Degree of comprehensive land use		0.0011	0.0018	0.0009

3.2 Characteristics of Landscape type

At the type level (Table 2), the Largest Patch Index (LPI) of farmland was the largest, and LPI of forestland was the second one during the period of studying. It indicates that the farmland and forestland was the dominant landscape type in the study area, and they played a controlling role in the landscape pattern of the whole Eastern Sichuan.

The patch density (PD) of farmland decreased and the LPI continued to increase during the period of 1990 -2000. From 2000 to 2015, the PD of farmland increased, and the LPI continued to decrease, indicating that farmland patches had been fragmented. The PD of forestland increased firstly and decreased later, with reaching a maximum value of 0.0207 in 2010 and dropping to the lowest value of 0.0192 in 2015. The LPI showed an increasing trend and the PD was decreased, indicating that the Grain to Green Projects focused more on the increase in the number of patches in forestland patches during the period 2000 to 2010 and focused on the connectivity of forestland patch from 2010 to 2015. The change trend of this landscape type was basically similar with the change of dynamic degree, which further illustrated the effect of the Grain to Green Projects was significant. The PD, LPI, the dimensions index, and shape index of building land all showed an increasing trend, indicating that the urbanization rate increased and at the same time people also focused on the rationality and aesthetics of urban space layout. The PD of grassland showed a decreasing trend but the LPI increased. And the fractal dimension index and shape index of grassland decreased. This represented the shape of the grass types become simplistic. We guess this pattern may be highly caused by human being factors such as the increase of urbanization or the Grain to Green Projects. There was no obvious impact on landscape characteristics of water land and unused land, because the area of them was so small.

Table 2. The information entropy of land use types in Eastern Sichuan, 1990-2015.

Types	Years	Patch Density	Largest Patch Index	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
	2015	0.019	41.8194	1.03	1.3495
Forestland	1990	0.0194	11.8403	1.0219	1.2678
	1995	0.0197	9.3884	1.0235	1.2685
Forestland	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
	2015	0.0192	23.8814	1.0208	1.2382
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
	2015	0.0155	1.9555	1.0229	1.2398
Water land	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
	2015	0.0053	0.0638	1.0142	1.1295
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
	2015	0.0053	0.2935	1.0132	1.1192
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
	2015	0.0002	0.0015	1.0017	1.0104

3.3 Landscape Pattern

From 1990 to 2015, the patch density in Eastern Sichuan was very similar, with reaching a maximum (0.0669) in 2010. However, fractal dimension index and shape index continued to decrease. And they fell from 1.0241 and 1.2793 at the beginning of the study to 1.0227 and 1.2509 respectively, indicating that the landscape pattern in Eastern Sichuan gradually tended to be equalized. The diversity index showed a complex trend. It dropped to the minimum of 1.034 in 1990 and reached a peak of 1.0546 in 2010. The increased degree of diversity index was significantly distinct after 2000. This represents the diversity of the landscape has increased and the spatial layout tends to be regular, which states that the Grain to Green Projects has also get a certain effect on the change of the overall level of the landscape pattern in the study area since 2000.

Table 3. Change of landscape pattern index in the Eastern Sichuan basin from 1990 to 2010.

Years	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
2015	0.065	1.0227	1.2509	1.0489

4. Conclusion

The main land use type was farmland in the study area. Since 2000, the area of farmland has been decreased but the area of forestland has been increased. This verifies that the implementation of the Grain to Green Projects obtains a significant effect. At the same time, For farmland types, the project promotes the fragmentation. For forestland types, it focuses on increasing the number of patches in the earlier period of the project, but increasing the connectivity in the later period. Given the change trend of building land types, we can also know that the project pays attention to the rationalized the spatial pattern of the overall region for getting maximized benefits of the regional ecosystem. However, the disturbance of human factors, such as the Grain to Green Projects, may have a certain impact on grassland types, which promotes the regularization of shape.

The Eastern Sichuan belongs to the important ecological barrier area in the hilly area of the upper and middle reaches of the Yangtze River. This study obtained valuable landscape structure information in land use management. It can provide appropriate information for the evaluation and planning of landscape patterns, and can also be used to support policy-making on ecological protection.

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