Evaluating the Effects of Grain for Green policy through the landscape change: A Case Study in Gannan region, China

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Abstract. Gannan region, an important ecological barrier in the Gan Jiang River basin, is a typical southern mountain-hill area in Jiangxi Province, China, and its ecological protection is of great significance. In this study, using data of 5-year intervals from 2000 to 2015, the landscape change in the Gannan region was investigated through the application of remote sensing, geographic information technology, and spatial statistical methods. The results show that (1) The landscape pattern of Gannan region tends to be fragmented and decentralized, the landscape shape tends to be complex, and the human interference becomes more difficult. (2) Forest is the main land type in the Gannan region and decreased over the 15 years of investigation from 3094200 ha to 3068200 ha. (3) The area of farmland was rising before 2010, and then drops rapidly. Grassland shows the opposite trend to farmland, which shows the effectiveness of the Grain for Green policy. This study provides a theoretical basis and a decision support mechanism for the rational layout and protection of ecological land in Gannan region. The results could lead to improved ecological barrier functions of southern hilly region.

1. Introduction

Land use/land cover change (LUCC) is an important part of global climate change and global environmental change research, and it is the link between human social economic activities and natural ecological processes [1-2]. The landscape pattern is determined by the type, number, size, shape and spatial distribution of the spatial heterogeneity of landscape elements, which is the result of the interaction of various complex physical, biological, and social factors [3]. Changes in landscape patterns are the result of combination between natural and human disturbances that reflect the way humans use natural resources and potential ecological insecurity factors [4]. Therefore, landscape dynamics has become the core of the research of the landscape ecology, and it is necessary for landscape planning and resources management [5,6]. Landscape metrics are also becoming important indicators for land use/cover change, habitat functions, landscape regulating functions and information functions [7]. Mountainous regions play an important role in ecosystem services. Landscape change in mountainous region places vital influence on the conservation of ecosystem functions [8-10].

Gannan region, an important ecological barrier in the Gan Jiang River basin, is a typical southern mountain-hill area in Jiangxi Province, China. The forestry resources in this region are abundant and the forest coverage rate is high, which is very important for regional climate regulation and ecological balance. The implementation of Grain for Green policy is an important measure to adjust the structure of the agricultural industries and promote rapid economic growth and the construction of ecological civilization. It is an effective way to increase forest and grass resources, improve ecological quality,
construct important ecological barriers in the south of China, and achieve the goal of “double increase” in forestry. Analysis of landscape patterns can help assess changes in local eco-environment since the implementation of the Grain for Green policy. It is of great significance to promote the improvement of the ecological environment in the region and the sustainable development of the ecological environment and the harmonious development of man and nature.

2. Study area and method

2.1. Study area
Gannan region is located in south of Jiangxi province, China (Fig.1), between 24°29′–27°09′ N, and 113°54′–116°38′ E, with total area 3.9347×10⁴ km². The altitude there varies between 78 meters and 1827 meters above sea level with an approximately average slope of 3.47 degrees. The annual average temperature is about 19.3 °C, and the annual precipitation is 1568.75 mm. Gannan region, an important ecological barrier in the Gan Jiang River basin, is a typical southern mountain-hill area, and its ecological protection is of great significance. The forestry resources are abundant, and the forest coverage rate reaches 74.54%. It is one of the commodity forest bases and key forest areas in China. The Grain for Green policy, the greatest ecosystem project, launched at 2000 in this area to protect the forest and grass in Gannan region. Its aim is to return agricultural land to rebuilt forest and grassland.

2.2 Methodology
Four Ecological land use maps, extracted from Landsat TM /ETM and Landsat 8 remote sensing images, covered the study area spanned the temporal frames of 2000 to 2015 (Fig.2) were used to monitor the achievements of the Grain for Green policy. The land use types in the area were classified into six types including farmland, forest, grassland, water area, built land and unused land. Landscape transition matrix and landscape indices, including Class Area (CA), Number of Patches (NP), Mean Patch Area (AREA-MN) Largest Patch Index (LPI), Landscape Shape Index (LSI), Aggregation Index (AI), Interspersion Juxtaposition Index (IJI), Shannon’s Diversity Index(SHDI), Shannon Evenness Index(SHEI), were calculated as indicators to evaluation the effects of the Grain for Green policy.
3. Results and analyses

3.1 Analysis of Dynamic Degree of Land Use
According to the overall degree of land-use dynamics, forest showed a decreasing trend, farmland, and grassland showed an increasing trend. Since the implementation of the Grain for Green policy, the area of forest increased from 2005 to 2010 and declined at other times. Since 2000, the area of grassland has changed from decrease to increase, and at the same time the farmland showed the opposite trend. This means that the Grain for Green policy has a significant effect, and after 2010, more farmland was converted to grassland. And it shows that the project of the Grain for Green policy has substantially reduced the rate of forest loss. The dynamic degree of comprehensive land use has risen over the past 15 years, which showed that in order to get maximized benefits of the regional ecosystem, this policy not only pursues a reduction in the area of farmland and an increase in forest, but also pays attention to the overall change in the landscape pattern.

Table 1. Dynamic degree of land use in Gannan region from 2000 to 2015

| Land use types                   | 2000-2005 | 2005-2010 | 2010-2015 |
|---------------------------------|-----------|-----------|-----------|
| Farmland                        | 0.427     | -0.078    | -0.161    |
| Forest                          | -0.011    | 0.005     | -0.027    |
| Grassland                       | -0.090    | -0.039    | 0.258     |
| Dynamic degree of comprehensive land use | 0.067    | 0.022     | 0.130     |

3.2 Landscape pattern dynamics in Gannan region
At landscape level (table 2), NP in the Gannan region decreased from 3180 to 3309 and AI presented a downward trend during 2000-2015. This showed that the landscape pattern of Gannan region is in a fragmented state and landscape heterogeneity was aggravated. The LSI rose from 30.8239 to 32.0714, which means the patch shape tends to be complicated. This situation indicated that the interference of human activities has decreased. SHDI and SHEI increased in 1990-2000. LPI decreased from 74.5246
in 1990 to 73.9952 in 2015. The results show that the proportion of dominant landscape types decreases, while the control of single landscapes decreases. The difference in the proportion of landscape types decreased, and the landscape heterogeneity increased.

Table 2. Indices comparison at landscape level in Gannan region from 2000 to 2015.

| Year | NP    | LSI  | AI   | LPI   | SHDI | SHEI |
|------|-------|------|------|-------|------|------|
| 2000 | 3180  | 31.22| 70.79| 74.68 | 0.77 | 0.43 |
| 2005 | 3174  | 31.45| 70.56| 74.46 | 0.77 | 0.43 |
| 2010 | 3169  | 31.33| 70.68| 74.54 | 0.77 | 0.43 |
| 2015 | 3309  | 32.07| 69.95| 74.00 | 0.79 | 0.44 |

NP: Patch Number; LSI: Landscape Shape Index; AI: Aggregation Index; LPI: Largest Patch Index; SHDI: Shannon’s Diversity Index; SHEI: Shannon Evenness Index; Interspersion Juxtaposition Index.

3.3 Change characteristics of landscape type in Gannan region

At class level (Table 3), forest was the main landscape type from 2000 to 2015, though its area decreased from 3094200 ha to 3068200 ha. Changes in CA indicate that the forest decreased and the grassland and farmland increased after the implementation of the Grain for Green policy. This means that forests were turning back to farmland while the implementation of reforestation. After 2010, the farmland dropped sharply, while the grassland increased, which means large amount of farmland converted into grassland. This also shows that the process of urbanization is accompanied by large number of peasant migrants leading to farmland reclamation, which translated into low-coverage grasslands. The NP of the three types of Ecological land including forest land, grassland and farmland increased, which indicated that the fragmentation of the landscape in Gannan region is more serious. The change in AREA_MN indicated that the fragmentation of the three types of ecological lands is intensified, among which the forest showed the most significant. The IJI of forest and farmland increased first and then decreased from 2000 to 2015, while the grassland showed the opposite trend. This means that the connectivity between forest and farmland was in a declining state, while the connectivity of grassland has increased. The LSI of three land types increased from 2000 to 2015, which means the shape of the three types of land use tended to be complicated, and human interference decreased. The LPI of forest declined from 74.6784 in 2000 to 73.9952 in 2015, This shows that the forest landscape dominance is declining.

Table 3. Indices comparison at class level in Gannan region from 2000 to 2015.

| Year | Landscape type | NP   | CA(ha) | LPI   | LSI   | AREA_MN   | IJI   |
|------|----------------|------|--------|-------|-------|-----------|-------|
| 2000 | Farmland       | 1715 | 710700 | 1.2352| 52.1361| 414.4023  | 37.7678|
|      | Forest         | 100  | 3094200| 74.6784| 30.9659| 30942     | 48.8836|
|      | Grassland      | 873  | 232800 | 0.2602| 35.0000| 266.6667  | 48.2388|
| 2005 | Farmland       | 176  | 724100 | 1.2522| 52.3743| 424.4431  | 37.5744|
|      | Forest         | 100  | 3085300| 74.4620| 31.2131| 308533    | 48.3191|
|      | Grassland      | 871  | 227600 | 0.2602| 34.7813| 261.3088  | 48.4089|
NP: Patch Number; CA: Class Area; LPI: Largest Patch Index; LSI: Landscape Shape Index; AREA-MN: Mean Patch Area; IJI: Interspersion Juxtaposition Index.

4. Conclusion
In this study, using data of 5-year intervals from 2000 to 2015, the landscape change in the Gannan region was investigated through the application of remote sensing, geographic information technology, and spatial statistical methods. The main conclusions of the change in landscape pattern since the implementation of Grain for Green policy were as follows:

(1) The landscape pattern of Gannan region tended to be fragmented and decentralized, the landscape shape tended to be complex, and the human interference became more difficult.

(2) Forest is the main land type in the Gannan region and has decreased over the 15 years of investigation from 3094200 ha to 3068200 ha.

(3) The area of farmland was rising before 2010, and then dropped rapidly. However, grassland showed the opposite trend.

In summary, the landscape shape tended to be complex, and human disturbances decline, but fragmentation and dispersion increased after carrying out the project of Grain for Green policy. Though there were more forest changed to farmland than farmland changed to forest during 2000 to 2015, the area of grassland increased, which indicating the actual effect of the Grain for Green policy. This ecosystem project reversed the rapid increase of farmland and the dramatic decline of grassland and forest land.

Forestland plays a key role in maintaining the ecosystem service value. In the future, development should focus on maintaining the advantages of the existing forest and actively promoting ecotourism tourism to enhance local economic benefits. At the same time, it is necessary to improve agricultural production techniques in order to improve the disadvantages of agricultural production brought about by the mountainous terrain.

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