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The Study on the dynamics of Landscape pattern in Xiangxi Region Based on RS/GIS

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Abstract. Xiangxi Region is on the edge of Yunnan-Guizhou Plateau which has complicated topography. It is a multi-nationality region which is the important protected area for resources and environment in China. Based on the data of Landsat TM/ETM image in 1990, 1995, 2000, 2005, 2010 and 2015, the change of landscape pattern in Xiangxi Region was analyzed by the use of ARCGIS and FRAGSTATS. The results showed that: (1)The area of farmland and forestland decreased. (2)The landscape patches in Xiangxi Region tended to be more fragmented and diversified but the shape of patches were more simple. (3)The fragmentation of farmland, building land and unused land was more serious. The patch shape of building land, water and wetland is more complicated. (4)These changes may be caused by the policy of grain for green and urban expansion. This study provides a strong theoretical basis for policy-making of environmental protection and management in Xiangxi Region of Hunan Province in China.

1. Introduction

Land Use/Cover Change (LUCC) is a key factor to impact on landscape structure, function and dynamics[1]. It also has significant impact on global climate change and sustainable development[2-3]. Pattern and process refer to the spatial relationship between different landscape or geographical units and the process of response to this kind of relation. Continuous change of landscape pattern may cause alteration in erosion, water and nutrients circulation[4]. Recent researches devote into define and quantify the spatial-temporal change of landscape structure, landscape fragmentation and heterogeneity. Spatial technology tools such as geographic information systems (GIS) and remote sensing (RS) have successfully helped ecologists to conduct these thoughts[5-7]. Studies of landscape ecology on urban and something related are more complete[8-10]. However, mountainous regions usually have high value of ecosystem service. And terrain closely relates to landscape pattern.

Xiangxi Region has high quality of natural resources, world natural heritage sites and historical and cultural cities. But the development of social-economic is relatively backward. The conflict between environmental conservation and economic development tends to be serious. It is significant to find out the reasonable use of different landscape types. In this study, Xiangxi Region was selected as a case study area to conduct appropriate analysis for studying landscape structural changes. Then, digital image processing techniques was used to obtain landscape classified maps in the years of 1990, 1995, 2000, 2005, 2010 and 2015. Based on ARCGIS and FRAGSTATS, five landscape pattern indices in landscape level and four indices in class level were chosen and calculated. Topography is complicated in this region. So terrain factors have been considered into the study. These results could provide a
strong theoretical support for better eco-environmental conversation and sustainable development in Xiangxi Region.

2. Study area and method

2.1. Study area

Xiangxi Region locates in the west of Hunan Province, including Shaoyang, Zhangjiajie, Huaihua, Loudi city and Xiangxi Tujia-Miao Autonomous Prefecture with total area of 8.169 km²(fig.2). It is the central region of four province boarder, between 108°47’—112°57’ longitude, and 25°58’—29°48’ latitude. The concept of Xiangxi was firstly proposed during Western Development. Xiangxi Region, from the elevation 50m to 1903m, has Wuling and Xuefeng Mountains and it’s surrounded by Yungui Plateau. It belongs to the subtropical monsoon humid climate with typical continental characteristics. The annual average temperature is about 17~18 ℃, and the annual precipitation is 1100~1600 mm. By the end of 2015, the resident population was 20.19 million, taking up 29.77% of Hunan Province. Gross domestic product in Xiangxi Region was 48.97 billion, taking up 16.09% of Hunan Province[11]. This region is a muti-ethnic region in the province and it’s the main area of 20 concentrated poverty-stricken counties in the western part of Hunan Province. The ecological development and environmental conservation are of great importance.

![Fig. 1. Location and zoning of Xiangxi Region](image)

2.2 Methodology

The remote sensing imagery data of year 1990, 1995, 2000, 2005, 2010 and 2015 with 1:250000 topographic map, soil and plant thematic map are used to divide landscape types into 7 categories: farmland, forestland, grassland, water, building land, unused land and wetland (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 in class level and landscape level.

DEM data was used to extract elevation and slope data in Xiangxi Region. And we used formula below to calculate topographic index, followed by gradient division(Tab.1). Then this study analyzed the dynamics of landscape pattern along different gradients.

\[
T = \ln \left[ \left( \frac{E}{E_0} + 1 \right) \times \left( \frac{S}{S_0} + 1 \right) \right]
\]  

(1)
Table 1. The gradients of topographic index setting in Xiangxi Region.

| Level | Gradient range |
|-------|----------------|
| 1     | 0.0-0.291      |
| 2     | 0.291-0.515    |
| 3     | 0.515-0.702    |
| 4     | 0.702-1.104    |
| 5     | 1.104-2.313    |

Fig. 2. Landscape types in Xiangxi Region from 1990 to 2015

3. Results and analyses

3.1 Change of characteristics of landscape type in Xiangxi Region

For 25 years from 1990 to 2015, farmland, forestland, grassland, unused land and wetland generally decreased in Xiangxi Region while water and building land increased. Forestland, as the largest landscape type in the study area, has reduced 23300 ha in 20 years from 1995 to 2015. Farmland, the second large landscape type, has decreased 50200 ha in 25 years, with 0.10% rate of decrease.
Wetland increased from 2005. Building land occupied 0.75% of entire area in 1990, but 1.32% in 2015, with 45300 ha increasing. Building land had the largest increasing rate up to 3.00%.

Xiangxi Region has been practicing the policy of grain for green and afterwards extended to convert farmland to wetland. The results possibly showed that returning farmland and increasing wetland have been completed better. Forestland occupied the most area in Xiangxi Region and the change of it is slight. However, urban expansion here is serious for the increasing rate of building land is much larger than other types. The area of water increased for flood control and water conservancy regulation use. In general, land resources have not been protected well in study region yet, because the natural types of landscape are on decline while building land is on opposite. It should take more actions to guarantee the sustainable use of land and healthier development of Xiangxi Region.

3.2 Landscape pattern dynamics of Xiangxi Region

3.2.1 Dynamics in landscape level

The data of increasing patch numbers (6024 in 1990 and 6274 in 2015) and patch density (0.072 in 1990 and 0.075 in 2015) showed that the landscape patches have become considerably fragmented during 25 years (Tab.2). The fractal dimension index is used to demonstrate the characteristics of landscape spatial distribution attributes. It can reveal the distribution of landscape patches and can subsequently reflect the aggregation or separation of those patches. The decrease of fractal index showed that landscape patch shape tended to simplify and the arrangement tended to be more closely and orderly. Shannon diversity index increased from 0.844 to 0.863 and contagion index decreased from 57.888 to 56.998. It means that landscape diversity increased in 25 years and so did the fragmentation in Xiangxi Region.

In summary, landscape heterogeneity, fragmentation and landscape diversity increased in the study area. Landscape patches tended to be rules and simplified.

| Year | NP  | PD  | FRAC_MN | SHDI   | CONTAG |
|------|-----|-----|---------|--------|--------|
| 1990 | 6024| 0.072| 1.02    | 0.844  | 57.888 |
| 1995 | 5877| 0.071| 1.02    | 0.839  | 58.185 |
| 2000 | 6001| 0.072| 1.02    | 0.843  | 57.954 |
| 2005 | 6022| 0.072| 1.02    | 0.846  | 57.815 |
| 2010 | 6081| 0.073| 1.019   | 0.85   | 57.629 |
| 2015 | 6274| 0.075| 1.019   | 0.863  | 56.998 |

NP: Patch number; PD: Patch density; FRAC_MN: Mean fractal dimension; SHDI: Shannon diversity index; CONTAG: Contagion index.

3.2.2 Dynamics in class level

Comparing year 1990 and 2015, patch number of farmland and unused land were increased. It indicated that the fragmentation of these two landscape types increased. And interspersion juxtaposition index (IJI) of these two types were both increased, showing that the distribution of farmland and unused land have trend to be segmented. The declining of the shape index of farmland these years indicated that farmland patches tended to simplify and it may result from the governors’ management and planning. The shape index of building land increased so its patches tended to be more complicated. Xiangxi Region is a mountainous region, so local people have to construct buildings along the mountains there and it possibly caused the increase of building land shape index.

The patch number and patch density of forestland, grassland, water and wetland decreased in study period. It closely related with the area change. Interspersion juxtaposition index of forestland, grassland and water were increased. Combined with patch number, these three landscape types tended to be segmented and fragmented. The shape index of forestland and grassland declined showing the
simplification of these two types’ patches. Although landscape patches tended to be simplified in the entire study area, individually, the shape index of water and wetland increased, so it meant their patches became more complex.

Table 3. Change of landscape pattern indices in class level in Xiangxi Region from 1990 to 2015.

| Landscape type | Year | NP   | PD     | SHAPE_MN | IJI   |
|----------------|------|------|--------|----------|-------|
| Farmland       | 1990 | 3199 | 0.0384 | 1.2398   | 23.2240|
|                | 1995 | 3163 | 0.0380 | 1.2350   | 22.9328|
|                | 2000 | 3249 | 0.0390 | 1.2395   | 23.2800|
|                | 2005 | 3254 | 0.0391 | 1.2382   | 23.5459|
|                | 2010 | 3256 | 0.0391 | 1.2385   | 23.9631|
|                | 2015 | 3281 | 0.0394 | 1.2367   | 25.3355|
| Forestland     | 1990 | 301  | 0.0036 | 1.3569   | 39.6529|
|                | 1995 | 281  | 0.0034 | 1.3971   | 39.9087|
|                | 2000 | 282  | 0.0034 | 1.3947   | 40.3245|
|                | 2010 | 280  | 0.0034 | 1.3977   | 40.8746|
|                | 2015 | 290  | 0.0035 | 1.3865   | 42.7878|
| Grassland      | 1990 | 1461 | 0.0175 | 1.1776   | 31.6948|
|                | 1995 | 1454 | 0.0174 | 1.1769   | 31.9331|
|                | 2000 | 1450 | 0.0174 | 1.1704   | 32.7968|
|                | 2005 | 1445 | 0.0173 | 1.1701   | 32.9847|
|                | 2010 | 1449 | 0.0174 | 1.1688   | 33.1844|
|                | 2015 | 1452 | 0.0174 | 1.1660   | 33.6164|
| Water          | 1990 | 565  | 0.0068 | 1.0408   | 52.2463|
|                | 1995 | 474  | 0.0057 | 1.0694   | 51.7189|
|                | 2000 | 551  | 0.0066 | 1.0631   | 50.8962|
|                | 2005 | 555  | 0.0067 | 1.0684   | 50.9219|
|                | 2010 | 557  | 0.0067 | 1.0653   | 51.8777|
|                | 2015 | 549  | 0.0066 | 1.0654   | 52.8885|
| Building land  | 1990 | 428  | 0.0051 | 1.0374   | 50.8702|
|                | 1995 | 418  | 0.0050 | 1.0296   | 51.5437|
|                | 2000 | 411  | 0.0049 | 1.0380   | 51.8864|
|                | 2005 | 426  | 0.0051 | 1.0403   | 52.1176|
|                | 2010 | 469  | 0.0056 | 1.0407   | 52.5354|
|                | 2015 | 630  | 0.0076 | 1.0495   | 51.5775|
| Unused land    | 1990 | 6    | 0.0001 | 1.1389   | 47.3053|
|                | 1995 | 9    | 0.0001 | 1.0000   | 50.1783|
|                | 2000 | 6    | 0.0001 | 1.0667   | 50.2424|
|                | 2005 | 6    | 0.0001 | 1.0667   | 50.2424|
|                | 2010 | 6    | 0.0001 | 1.0667   | 50.2424|
|                | 2015 | 7    | 0.0001 | 1.0357   | 51.0686|
| Wetland        | 1990 | 72   | 0.0009 | 1.0116   | 69.4625|
|                | 1995 | 58   | 0.0007 | 1.0259   | 63.6678|
|                | 2000 | 53   | 0.0006 | 1.0126   | 65.9842|
|                | 2005 | 54   | 0.0006 | 1.0123   | 62.4050|
|                | 2010 | 64   | 0.0008 | 1.0156   | 61.9228|
|                | 2015 | 65   | 0.0008 | 1.0205   | 62.9199|
NP: Patch number; PD: Patch density; SHAPE_MN: Mean shape index; IJI: Interspersion juxtaposition index.

3.3 Change of landscape pattern along topographic index gradient in Xiangxi Region

On average, patch number and patch density in Xiangxi Region reached a peak on the second gradient of topographic index. And these two indices decreased ranging from level 2 to level 5. This indicated that the most serious fragmentation occurred on second and third gradient, and the higher topographic index, the slighter fragmentation. Fractal dimension increased from level 1 to level 4 but fell on level 5, approximately showing that more landscape patches with complicated shape spread on higher topographic index gradient. This may result from the management of governors’ on lower gradients. Shannon diversity index declined as gradient up which meant the landscape diversity decreased with rising gradient. The increase of contagion index as gradient up also showed that fragmentation and segmentation were more serious on lower topographic index gradient.

During the study period, patch number and patch density increased on level 1 and level 3 while decreased on level 2, level 4 and level 5 over time. It may showed that on level 1 and 3, landscape tended to be more fragmented and on other gradient levels connectivity tended to be better. Fractal dimension increased on level 2 and 4, decreased on level 3, increased firstly and then decreased on level 1 and 5. This indicated that the landscape shape on level 2 and 4 tended to be more complicated and irregular. However, diversity index on all gradient levels were increased with time, showing the increasing of landscape diversity on every topographic index gradients. Contagion index on level 1, level 4 and level 5 declined and on level 2 and 3 increased over time.

In summary, the more serious fragmentation commonly occurred on lower topographic index gradient. And the landscape on the first gradient of topographic index became more fragmented and it became more connected on second gradient of topographic index.

Table 4. Change of landscape pattern indices in landscape level along topographic index gradient in Xiangxi Region from 1990 to 2015.

| Level | Year | NP   | PD   | FRAC_MN | SHDI | CONTAG |
|-------|------|------|------|---------|------|--------|
| 1     | 1990 | 2382 | 0.1433 | 1.0142 | 0.9644 | 51.4911 |
|       | 1995 | 2368 | 0.1425 | 1.0145 | 0.9724 | 46.9449 |
|       | 2000 | 2407 | 0.1449 | 1.0143 | 0.9732 | 50.9785 |
|       | 2005 | 2419 | 0.1457 | 1.0142 | 0.9826 | 50.5316 |
|       | 2010 | 2432 | 0.1464 | 1.0142 | 0.9914 | 50.0528 |
|       | 2015 | 2474 | 0.149  | 1.0141 | 1.0269 | 48.1901 |
| 2     | 1990 | 3260 | 0.1956 | 1.0149 | 0.8515 | 53.6424 |
|       | 1995 | 3249 | 0.1948 | 1.0146 | 0.8373 | 54.5080 |
|       | 2000 | 3198 | 0.1922 | 1.0150 | 0.8412 | 57.9480 |
|       | 2005 | 3203 | 0.1925 | 1.0150 | 0.8432 | 57.7898 |
|       | 2010 | 3210 | 0.1929 | 1.0150 | 0.8479 | 57.4752 |
|       | 2015 | 3224 | 0.1937 | 1.0150 | 0.8579 | 56.8774 |
| 3     | 1990 | 3093 | 0.1861 | 1.0159 | 0.7439 | 59.9020 |
|       | 1995 | 3143 | 0.1895 | 1.0153 | 0.7530 | 59.4517 |
|       | 2000 | 3131 | 0.1889 | 1.0155 | 0.7620 | 62.1914 |
|       | 2005 | 3127 | 0.1887 | 1.0156 | 0.7635 | 62.1467 |
|       | 2010 | 3124 | 0.1885 | 1.0156 | 0.7647 | 62.1151 |
|       | 2015 | 3142 | 0.1896 | 1.0155 | 0.7738 | 61.5661 |
| 4     | 1990 | 3088 | 0.1864 | 1.0166 | 0.7678 | 61.6577 |
|       | 1995 | 3029 | 0.1830 | 1.0165 | 0.7489 | 62.6919 |
|       | 2000 | 3008 | 0.1821 | 1.0174 | 0.7595 | 62.2066 |
|   |   |   |   |   |
|---|---|---|---|---|
| 2005 | 3009 | 0.1822 | 1.0174 | 0.7609 | 62.1412 |
| 2010 | 3012 | 0.1824 | 1.0174 | 0.7615 | 62.1020 |
| 2015 | 3021 | 0.1829 | 1.0173 | 0.7687 | 61.7057 |
| 1990 | 1785 | 0.1081 | 1.0157 | 0.6865 | 65.6114 |
| 1995 | 1760 | 0.1066 | 1.0170 | 0.6837 | 65.7924 |
| 2000 | 1774 | 0.1077 | 1.0165 | 0.6921 | 62.5582 |
| 2005 | 1770 | 0.1074 | 1.0165 | 0.6923 | 62.5607 |
| 2010 | 1770 | 0.1074 | 1.0165 | 0.6928 | 62.5378 |
| 2015 | 1775 | 0.1077 | 1.0164 | 0.6982 | 62.2184 |

NP: Patch number; PD: Patch density; FRAC_MN: Mean fractal dimension; SHDI: Shannon diversity index; CONTAG: Contagion index.

4. Conclusion
Different landscape types have different dynamics change from 1990 to 2015. The area of farmland, forestland, grassland, unused land and wetland has decreased while the water and building land has increased. This change possibly caused by the conduction of grain for green policy. And it is noteworthy that urban expansion in Xiangxi Region is serious for building land increased more fast than that of other areas.

The fragmentation in Xiangxi Region has trend to be serious but the shape of patches were more simple under human disturbance and management possibly. Individually, the fragmentation of farmland, building land and unused land was more serious. The patch shape of building land, water and wetland was more complicated.

The fragmentation in Xiangxi Region was less serious as topographic index increased. But the shape of patches was simpler on lower gradients. On temporal change, landscape on the first topographic index gradient was more fragmented and landscape on the second gradient was more connected.

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References
[1] J.G. Wu. Ten key research topics in landscape ecology. Acta Ecol. Sin 24, 2074-2076 (2004)
[2] Q.D. Fan, S.Y. Ding. Landscape pattern changes at a county scale: A case study in Fengqiu, Henan Province, China from 1990 to 2013. CATENA, 137, 152-163 (2016)
[3] J.Y. Liu, M.L. Liu, H.Q. Tian. Spatial and temporal pattern of China cropland during 1990-2000: Analysis based on Landsat TM data. REMOTE SENS ENVIRON, 98, 442-456 (2005)
[4] F.R. Kearns, N.M. Kelly, J.L. Carter et al., A method for the use of landscape metrics in freshwater research and management. LANDSCAPE ECOL, 20, 113-125 (2005)
[5] A. Morán-Ordóñez, S. Suárez-Seoane, L. Calvo. Using predictive models as a spatially explicit support tool for managing cultural landscapes. APPL GEOGR, 31, 839-848 (2011)
[6] J.G. Polhill, A. Gimona, R. Aspinall. Agent-based modelling of land use effects on ecosystem processes and services. Journal of Land Use Science, 6, 75-81 (2011).
[7] F. Geri, V. Amici, D. Rocchini. Human activity impact on the heterogeneity of a Mediterranean landscape. APPL GEOGR, 30, 370-379 (2009)
[8] I.R. Malaque, M. Yokohari, M. Iii. Urbanization process and the changing agricultural landscape pattern in the urban fringe of Metro Manila,Philippines. ENVIRON URBAN, 19, 191-206 (2016)
[9] E.A. Gage, D.J. Cooper. Relationships between landscape pattern metrics, vertical structure and surface urban Heat Island formation in a Colorado suburb. URBAN ECOSYST, 20, 1229-1238 (2017)
[10] S. Park. Spatiotemporal Landscape Pattern Change in Response to Future Urbanisation in Maricopa County, Arizona, USA. LANDSCAPE RES, 38, 625-648 (2013)
[11] Hunan Provincial Bureau of Statistics. 2016 Hunan Statistical Yearbook (2016)