Dynamic Change of Landscape Pattern at Jilin Province from 1980 to 2000

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Abstract  By using remote sensing images from three periods (1980, 1995, 2000) and with the support of GIS and RS, the spatial information of landscape elements of Jilin Province from 1980 to 2000 was interpreted and extracted. Using models of landscape indices such as diversity, fragmentation, and mean patch fractal dimension, dynamic spatio-temporal changes of landscape patterns of the province were analyzed. The results: ① cropland and forestland were the main landscape types, and forestland became a landscape matrix; ② in the study area, landscapes were distributed unevenly, and there was low heterogeneity, a simple ecosystem structure and a tendency of irrational landscape patterns. There were also simple spatial shapes of patches and strong self-similarities, and in terms of dynamic change analysis, patch shapes tended to be more simple; ③ from 1980 to 2000, holistic landscape fragmentation was low and changed slightly. As far as landscape elements were concerned, the fragmentation of grassland, water area, land for residential area and factory facilities was relatively low; land distribution for residential areas and factory facilities was dispersed; and cropland and forestland were most concentrated — an indication that the trend will continue. Comprehensive effects among human activity, local policy, regional climate and environmental change led to the results.

Keywords  Jilin Province; dynamic change; landscape index; landscape pattern

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Introduction

Landscape ecology mainly studies structure, function, and change of landscape\(^1\), with spatial pattern as one of the main contents\(^2\). Landscape pattern refers to type, number, spatial distribution and location of landscape cells\(^3\). By analyzing dynamic changes of landscape pattern and spatial relation of landscape patches, we can analyze amounts, location, type, shape, area, and direction of landscape cells; evaluate the macro, regional, and ecological environment and forecast future tendency; and reveal dominant factors and driving factors of formation and development of landscape pattern that will ultimately help promote landscape sustainability. In this paper, through distribution maps of landscape of Jilin Province in 1980, 1995, and 2000, we obtained attributes and graphics data of various landscape types, and established a spatial information database with the support of ArcView and Arc/Info to study the dynamic changes of landscape pattern in the province from 1980 to 2000.

1  Methodology

Jilin Province stands in the middle of northeast China (E121°-E131°, N41°-N46°), covering an area of 178 400 km\(^2\); the east-west direction and south-
north direction cover distances of 650 km and 300 km, respectively.

1.1 Data processing and landscape types

We obtained MSS remote sensing images of Jilin Province in 1980 and Landsat TM remote sensing images of Jilin Province in 1995 and 2000. Standard false color composites (7,5,4 bands of MSS image; 4,3,2 bands of TM image) were executed using ERADS software. According to topographic maps of Jilin (1:100 000 scale), precise geometric correction and resampling with respect to the images of 2000 were executed, then an equal-area conical projection (ALBERS) of two standard parallels was performed. We used a 2-order polynomial to accomplish geometric correction of the images, and the resample achieved by cubic convolution with matching error under one pixel. Other images were matched with the images in 2000, followed by spatial enhancement of the images through contrast transform and histogram equalization. By using Arcview and Arc/Info software, integrating field surveying, various maps and documentation, we extracted spatial information of different landscape types (see Fig.1, Fig.2, 1-6 denote cropland, forestland, grassland, water area, land for residential area and factory facilities, unused land, respectively).

1.2 Indices of landscape pattern analysis

1) Landscape diversity index\(^4\) refers to the abundant, complex degrees of land use types and reflects the number of landscape elements and the proportion change of each landscape element. Theoretically, the index becomes highest on condition that the proportion of each landscape is equivalent.

2) Landscape fragmentation index\(^5\) refers to the fragmentation degree of segmented landscape and, to some extent, reveals disturbance from human activities to landscapes.

3) Landscape dominance index\(^6\) measures the extent to which one or a few landscape types are dominant.

4) Landscape evenness index\(^6\) describes the degree of even landscape distribution - the larger its value, the more even the distribution of landscape elements is.

5) Landscape isolation index\(^4\) reflects the individual distribution of various patches of the same land type in one region and denotes the separating degree of individual patch distribution in a certain landscape.

6) Mean patch fractal dimension (MPFD)\(^7\) usually measures the complex degree of patch shape. To some extent, it reflects the influences of natural factors and human activities to landscape pattern. The value of MPFD is between 1 and 2; if the closer it is to 1, the more simple the patch shape, the closer it is to 2, the more complex the patch shape.

2 Results and analysis

In terms of Fig.1, Fig.2, and the formulas of landscape indices, we obtained various landscape indices in 1980, 1995, 2000 (Table 1, Table 2).

![Fig.1 Dynamic changes of landscape area from 1980 to 2000](image1)

![Fig.2 Dynamic changes of landscape patch amounts from 1980 to 2000](image2)

| Year  | Diversity index | Dominance index | Evenness index | Fragmentation Index | Mean patch fractal dimension |
|-------|-----------------|-----------------|----------------|---------------------|-----------------------------|
| 1980  | 1.860 38        | 0.724 58        | 71.97%         | 0.016 13           | 1.046 76                    |
| 1995  | 1.835 20        | 0.749 76        | 70.99%         | 0.003 35           | 1.048 38                    |
| 2000  | 1.787 36        | 0.797 60        | 69.14%         | 0.015 51           | 1.046 49                    |
Table 2  Landscape pattern indices change in Jilin Province from 1980 to 2000(2)

| Landscape pattern | Year | Cropland | Forestland | Grassland | Water area | Land for residential area and factory facilities | Unused land |
|-------------------|------|----------|------------|-----------|------------|-----------------------------------------------|-------------|
| Isolation index   | 1980 | 0.388 48 | 0.327 05   | 1.554 77  | 2.474 68   | 6.452 28                                      | 1.114 39    |
|                   | 1995 | 0.366 19 | 0.337 08   | 1.449 06  | 2.406 68   | 6.143 33                                      | 1.430 37    |
|                   | 2000 | 0.358 44 | 0.344 36   | 2.044 74  | 2.744 56   | 6.294 48                                      | 1.077 58    |
| Fragmentation index| 1980 | 0.294 90 | 0.287 56   | 0.004 34  | 0.002 22   | 0.002 5                                       | 0.062 21    |
|                   | 1995 | 0.265 37 | 0.289 18   | 0.039 92  | 0.032 89   | 0.014 81                                      | 0.017 95    |
|                   | 2000 | 0.303 13 | 0.443 66   | 0.002 88  | 0.001 88   | 0.002 5                                       | 0.058 34    |

2.1 Dynamic change analysis of landscape patch amounts

As far as the studies of landscape changes and their re-distribution are concerned, the amount changes of landscape patches are quite important. Shown as Fig.1 and Fig.2, the patch number of land for residential areas and manufacturing facilities was the largest, but its area was relative smaller. Cropland and forestland became dominating landscapes of the study region and to a great extent, they controlled the landscape pattern. The area change of various landscapes was as follows. In the whole study period (1980-2000), the area of cropland and forestland increased slowly, with annual growing rates of 0.298% and 0.022%, respectively. From 1980 to 1995, the area of grassland, water area, and land for residential areas and factories grew slightly, but dropped during 1995-2000; in particular, grassland and water area descended so rapidly that their annual decreasing rates reached 6.527% and 4.206%, respectively. Overlapping the maps show that grassland and water area were mainly converted into cropland and unused land, which were mostly attributed to drought and declining rainfall for the study area, particularly west Jilin. At the same time, a high number of grasslands were degraded and led to an increase in the area of unused land. In terms of the total number of patches, during 1980-1995, the amount of patches dropped from 82 435 to 81 201 but grew from 81 201 to 81 614 during 1995-2000. The total number of patches and the amount of various landscape patches did not change drastically, indicating that the degree of both development and fragmentation of the whole landscape in the study region were lower. The declining rate of grassland area and water area was greatly higher than that of their patch amounts, which indicated that their fragmentation degree was relatively serious.

2.2 Dynamic analysis of diversity of landscape types

Diversity of landscape types is usually measured by diversity index, dominance index, and evenness index. Its ecological significance mainly refers to effects of biological diversity, and it has a strong impact on ecological processes such as runoff and erosion[8]. According to Table 1, during 1980-2000, the dominance index was always more than 0.7 and the diversity index and evenness index relatively low, which indicated that few landscapes held the dominant status. Various landscape types were distributed unevenly and heterogeneity was higher, which was mainly attributed to the relatively larger area of cropland and forestland. The dominance status became apparent and showed a growing tendency. Various indices of landscape in the study region changed dynamically, with the diversity and evenness indices representing a continuous decline and the opposite trend for the dominance index. Due to the obvious dominance of high homogeneous cropland and forestland, land use system developed towards order character and ecological structure became unreasonable. From 1980 to 2000, the area of cropland and forestland occupied more than 80% of total land area of the study site, controlling landscape pattern to a great extent. Meanwhile, other landscape types accounted for smaller proportions and were distributed unevenly, and the simple structure of the ecological system greatly limited their functions. At the same time, landscape pattern of the study region tended towards irrationality, and the extent to which various land use types controlled land use structure was not unbalanced. The findings above had a close relation to natural resources of the study area and the macro
policies of the Jilin Province government such as strict land management, strengthening cropland protection, and developing forest resources over the next few decades. Meanwhile, the worsening ecological environment, grassland degradation, increasing number of unused lands (mainly saline-alkalized and desertification land) had a strong impact. Thus, effective measures should be taken to optimize the ecological system, regulate the area of various landscape types, and exert their functions as soon as possible.

2.3 Dynamic analysis of diversity of landscape pattern

Indicators of landscape pattern diversity include isolation index, fragmentation index, and mean patch fractal dimension, which refer to the spatial distribution diversity of landscape and association of spatial relations and functions among various patches and landscape types. As seen from Tables 1 and 2, from 1980 to 2000, MPFD was close to 1 and changed slightly, which indicated minimal shape changes of landscape patches, simple spatial shapes, strong and self-similarity. The number of linear patches with the effects of corridors became small; transmission efficiency among energy, information, and species became lower, and dynamic change became more simple. Patch shape depends on surface configuration of natural physiognomy. There are plains in the middle and western part of the study region and mountainous area in the east part. This mountainous area accounts for a smaller percentage, so surface configuration of physiognomy simplified patch shape. During 1980-2000, the lower fragmentation indices of both the whole landscape and each landscape showed that the integration of landscape consisting of larger patches was better; minimal disturbances from human activities led to a lower development degree of the study area, and connectivity of landscape was higher, making the fragmentation phenomenon of landscape less obvious. The fragmentation index of the whole landscape decreased from 0.01613 to 0.00335 during 1980-1995, then increased to 0.01551 in 2000. These changes proved that the landscape fragmentation degree became low from 1980 to 1995, and larger patches began to cluster gradually as the number of small patches declined. In this period, by integrating and reclaiming various land use types, fragmented lands of low utility efficiency were combined into some large blocks of lands, which markedly enhanced the intensity of land use, and landscape patches shape became more simple. During the period of 1995-2000, the fragmentation degree was enhanced, and some large clustering patches were disintegrated step by step, the number of small patches grew, and the whole pattern became more complex. These dynamic changes enhanced interaction within landscapes and promoted the exchange of species, matter, and energy, which improved biological diversity and stability of the ecological system.

Shown as Table 2, during 1980-2000, as a result of the centralized distribution of grassland and water area, significant human disturbances, and the development of pieces of land, the fragmentation indices of grassland, water area, and land for residential areas and facilities became relatively low. From 1980 to 1995, the fragmentation indices of all the landscapes except cropland and unused land increased with varying extent, which revealed that the fragmentation degree of landscape became more serious. During 1995-2000, the fragmentation indices of cropland, forestland, and unused land increased, with the growth rate for forestland reaching 10.68% as the fragmentation indices of other landscape types started to drop. These changes were mostly attributed to the growing number of unused lands that were exploited, the rotating cultivation between cropland and grassland, and the occupation of cropland for building factories. Over-cutting of sparse forests, particularly in the countryside, and converting cultivated land to forestland and forestation in some regions (for example the west Jilin Province) improved the fragmentation degree of cropland, forestland, and unused land. In the last 20 years, the fragmentation indices of grassland and land for residential area and facilities changed drastically, in the first period (1980-1995), their annual growth rates reached 54.65% and 32.67%, respectively, while in the second period (1995-2000), their annual decreasing rates were 18.56% and 16.62%, respectively. This indicated that the status of landscape was unstable, and human ac-
tivities exerted a strong impact on landscape patterns. The unreasonable use of grassland resources and building cities and townships were the leading factors driving that instability.

In terms of the isolation indices of different landscapes in various periods as shown as Table 2, the isolation degree of land for residential areas and facilities was the largest. On one hand, this indicated how spatial distribution became dispersed. On the other hand, it was mixed together with other landscapes, and the isolation degree of water area, grassland, and unused land was larger, while that of cropland and forestland was the smallest and pieces of croplands and forestlands were centralized together. During 1980-1995, the isolation indices of forestland and unused land grew, while other landscapes decreased. These changes proved that forestland and unused land were segmented further by other landscapes, and the isolation degree among patches increased, while change trends of other landscapes were opposite. From 1995 to 2000, the isolation indices of cropland and unused land dropped, which indicated that their spatial distribution represented a relatively centralizing, even tendency, while the isolation indices of other landscapes increased because of the double effect of human activities and natural factors.

3 Conclusions

From 1980 to 2000, as a whole, patch amounts of landscape changed slightly and development degree was lower in the study region. Dynamic changes of landscape diversity showed that landscape pattern of the study area represented an unreasonable tendency. The structure of the ecological system was relatively simple, and in different phases, the diversity of spatial pattern changed drastically, which had a close relation to human activities, local policies, regional climate, and change of the ecological environment. In the future, the area of cropland and forestland will continuously and slightly increase. Their dominant status will be strengthened and the fragmentation degree will grow. Grassland and water areas will keep on declining, fragmentation degree will decrease, and the area of land for residential areas and facilities will change lightly. The development of unused lands is considered a future key to long-term planning of the study region.

References

[1] Xiao Duning, Li Xiuzhen, Gao Jun, et al.(2004) Landscape ecology[M]. Beijing: Science Press (in Chinese)
[2] Forman R T T, Godron M(1986)Landscape ecology[M]. New York: Wiley
[3] Chen Wenbo, Xiao Duning, Li Xiuzhen(2002)The characteristics and contents of landscape spatial analysis[J]. Acta Ecologica Sinica, 22(7): 1 135-1 142 (in Chinese)
[4] Tian Guangjin, Zhang Zengxiang, Zhang Guoping, et al.(2002) Landscape dynamic change pattern of Haikou City by TM imagery and GIS[J]. Acta Ecologica Sinica, 22(7): 1 028-1 034 (in Chinese)
[5] Ding Shengyan, Liang Guofu(2004)Landscape pattern change of regional wetland along the Yellow River in Henan Province in the last two decades[J]. Acta Geographica Sinica, 59(5): 653-661 (in Chinese)
[6] Zhang Xingfu, Xu Danghui, Wang Hui, et al.(2004)Study on the dynamic variation of landscape pattern in the middle and lower reaches of the Shule River Basin[J]. Journal of Lanzhou University(Natural Sciences), 40(4): 81-85 (in Chinese)
[7] Li Habin(1989)Spatio-temporal pattern analysis of managed forest landscapes: a simulation approach[D]. Oregon: Oregon State University
[8] Wang Xiaoyan, Xu Zhigao, Yang Mingyi, et al. (2004) Analysis of the landscape diversity dynamics of small watershed in the Loess Plateau[J]. Chinese Journal of Applied Ecology, 15(2): 273-277 (in Chinese)
[9] Fu Bojie(1995)The spatial pattern analysis of agricultural landscape in the Loess Area[J]. Acta Ecologica Sinica, 15(2): 113-120 (in Chinese)