Landscape Pattern Dynamic Change Research of Harbin Songbei Based on GIS Technology

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Abstract: With the rapid development of social economy in the Songhua River basin, there are big dynamic change of the landscape of the new area beside the river bank, which is represented by Harbin Songbei. This paper selects 13 representative indexes from landscape and patch level, analyzes the cause and process of the change of landscape pattern in Songbei during 2005-2015, and probes into the characteristics of the change based on the principle of landscape ecology, using remote sensing and GIS technology and Fragstats3.3 software data statistics.

1. General Situation of Research Area

Songbei District is located at 126°9’45’’-126°42’59’’E and 45°44'20"-46°5'5"N, which is one of the districts governed by Harbin City of Heilongjiang Province and a district development zone approved by the State Council in February 2004. Its south end is next to the South River Bank of Harbin Section of Songhua River, and its north end is next to the South Bank of the Hulan River; Its west end is adjacent to the Zhaodong City and its east end is next to the Red East Bank and the Sanjiazi Bank at the east of the railway beside the river bank. Songbei District has a total area of 736 km^2, of which the water area is 88 km^2, which has obvious geographical advantage, abundant natural resource, good ecological environment and broad space for development. In addition, the landform type of Songbei District belongs to inland river plain. The undulation is natural and gentle, and it has floodplain marsh wetland, flat area, gentle slope, hillock and depression. In general, the altitude is between 115 m to120 m, and the highest elevation is 165 m. In addition, this district belongs to the middle-temperate-zone semi humid continental monsoon climate, with long winter and short summer. Moreover, it is dry and windy in spring, warm and rainy in summer, short and early frost in autumn, cold and snow in winter. The annual average temperature is 3.2 ℃, the average annual rainfall is 578.8 mm, which is mainly concentrated from the July to August. The area beside the river bank are formed into the unique wetland landscapes such as multi islands, multi rivers, multi lakes as well as multi beaches due to the rich wetland resource in Songbei District.

2. Data Processing and Research Method

The basic data mainly includes the land use data in Songbei District of Harbin City in 2005, 2010 and 2015, in which the land use data in 2005 and 2010 was mainly from the “National Land Use Database 1:10 Ten Thousand” of Chinese Academy of Sciences, and the land use data in 2015 was mainly obtained through human-computer interactive visual interpretation on the basis of the land use data in 2010. By selecting the Landsat8 OLI image with less cloudiness and full coverage in 2015, conducting

the image fusion between the standard false color image synthetized from 5, 4 as well as 3 bands with 30 m resolution and the panchromatic band with 15 m resolution, the standard false color image with 15 m resolution can be generated. After geometric correction, image enhancement and other processes, the inspection, identification, interpretation and correction should be conducted and combined with the field survey on the basis of the remote sensing image and land use data in 2010 and 2015. Finally, the land use status and its change data in 2015 with relatively high accuracy can be obtained. Based on the land use data, the landscape types can be divided into 6 types: Cultivated land, wood land, grass land, water area, construction land and unused land.

Figure 1. Administrative district map in Songbei District of Harbin City.

2.1. Research Method

2.2.1 Spatial Statistical Analysis. Based on the land use data, the ArcGIS spatial analysis function was utilized, the spatial information database was established, the land use information was divided into six landscape types, the drawing and data statistic of the landscape type information of Songbei District in 2005, 2010 and 2015 were conducted. Based on spatial statistic information, it is found that the landscape type areas and spatial distribution characteristics were different, the distribution law was revealed, the regional landscape pattern and dynamic change trend of Songbei District was analyzed and researched [5].

*2.2.2 Transition Matrix.*The landscape type transformation was originated from the quantitative descriptions of the transitions between 6 different landscape types in the system analysis. More specifically, the landscape types in different time periods were supported by ArcGIS platform, the landscape type attribute table was exported, the PivotTable was inserted in Excel, and the transition matrix of landscape types in different time periods were established respectively. In addition, the two-dimensional table was used to reflect the landscape type change in the research area between 2005 and 2010 as well as between 2010 and 2015 in order to realize a quick view of the mutual transformation between different landscape types. Through the transition matrix analysis, that is, the mutual transformation relationship between different landscape types in different regions during different time periods, on the one hand, the quantitative description of the landscape patch type's change area in the research area was conducted, on the other hand, the increased or decreased areas of different landscape types coming from or transforming into which landscape patch type were reflected, which can further reveal its variation characteristic [8].

*2.2.3 Landscape Pattern Index.*The landscape pattern index refers to the quantitative index which can highly condense the landscape pattern information to reflect the structure composition and spatial allocation characteristic. It is the most commonly used method to adopt the landscape pattern index to conduct the quantitative description in the landscape pattern change analysis [9-10]. According to the research need and the self characteristic of the research area, the Fragstats3.3 software was used to calculate the landscape pattern index. In this paper, landscape index was selected from landscape level and type level, and 13 representative indexes were selected although there were still some limitations [11].

More specifically, 7 indexes were selected at the landscape level: patch density (PD), largest patch Index (LPI), average patch size (AREA-MN), average patch fractal dimension (FRAC-MN), landscape shape index (LSI), landscape aggregation index (AI) and Shannon diversity index (SHDI). 6 indexes were chosen at the patch type level: patch density (PD), largest patch index (LPI), landscape shape index (LSI) and patch separation index (SPLIT) [12-14].

3. Result and Analysis

3.1. Analysis on the Change of Landscape Element Area

Songbei District of Harbin City has a total area of 743.28 km^2. Based on the land use data in 2005, 2010 and 2015 (Figure 2-4), the statistics of area quantity information of six landscape types were conducted (Table 1). According to the statistical results: The proportions of Cultivated land landscape to the total area of Songbei District were 69.51%, 67.38% and 68.51% in 2005, 2010 and 2015 respectively, the Cultivated land landscape was the absolute advantageous landscape type in Songbei District, which occupied a dominant position. The change of construction land was relatively large, and part of the change was concentrated in the Songhua River coast. The construction land areas were 48.13 km^2 and 66.00 km^2 in 2005 and 2010 respectively, accounting for the 6.48% and 8.88% in the research area respectively. In 2015, the area of construction land had reached 108.41 km^2, covering an area ratio of 14.59%, which was about 3 times the proportion of construction land in 2005. Contrary to the situation of wild growth of construction land, the water area showed a rapid decline in the trend. In 2005, the covered area of water area was 95.86 km^2, accounting for 12.89% in the research area. In 2015, the covered area of water area reduced to 35.22 km^2, accounting for only 4.74% in the research area. Besides, the area of grass land increased at first and then decreased, which increased from 38.53 km^2 in 2005 to 82.68 km^2 in 2010 and then decreased to 34.37 km^2 in 2015. In all, the areas of construction land, water area, grass land and other landscape elements fluctuated greatly with time, which reflected that the landscape stability in the research area was poor and the research area belonged to the ecological sensitive area.

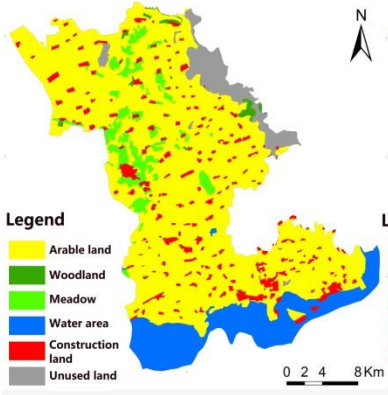

Figure 2. Present situation of land use in Songbei District in 2005.

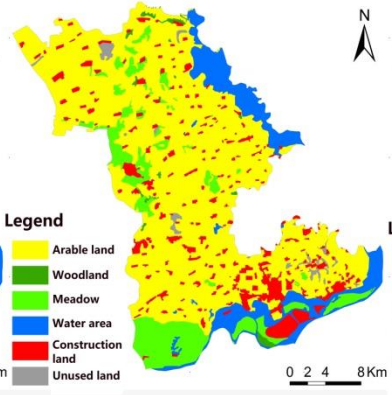

Figure 3. Present situation of land use in Songbei District in 2010.

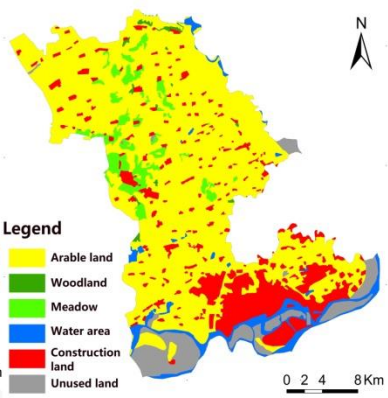

Figure 4. Present situation of land use in Songbei District in 2015.

Table 1. Ecosystem composition in Songbei District.

	2005		2010		2015	
	Area	Proportion%	Area	Proportion%	Area	Proportion%
Cultivated land	516.63	69.51	500.81	67.38	509.21	68.51
Wood land	5.33	0.72	5.45	0.73	3.81	0.51
Grass land	38.53	5.18	82.68	11.12	34.37	4.62
Water area	95.86	12.90	79.44	10.69	35.22	4.74
Construction land	48.13	6.48	66.00	8.88	108.41	14.59
Unused land	38.80	5.22	8.90	1.20	52.26	7.03

3.2. Analysis and Evaluation of Landscape Transformation Characteristic

ArcGIS 10.0 software was used to conduct the matrix operation and spatial statistical analysis, the landscape element transition matrix between 2005 and 2010, between 2010 and 2015 as well as each year from 2005 to 2015 were obtained. It can be seen from Table 2 that the landscape type transformation mainly occurred among the Cultivated land, water area and construction land in Songbei District of Harbin City between 2005 and 2015. From 2005 to 2010, there was 49.16 km^2 of Cultivated land transformed into other landscape types, in which 24.45 km^2 was transformed into the construction land, accounting for 49.74% of the total transformation area of Cultivated land; From 2010 to 2015, the transformation area of Cultivated land was 46.01 km^2, in which the area transformed into construction land increased to 36.44 km^2 obviously, accounting for 79.20% of the total transformation area of Cultivated land. In addition, the speed of construction land to occupy Cultivated land had been accelerated, and it was expanded along the Songhua River revetment to both sides and inland, which was the typical characteristic of urban expansion of the new District cities which in the area beside the river bank. Influenced by the development in the area beside the river bank, the water area landscape was seriously affected, the area covered by water area decreased from 95.86 km^2 in 2005 to 35.22 km^2 in 2015. From 2005 to 2010, there was 57.85 km^2 of the water area transformed into other landscape types, in which 46.87 km^2 of water area was transformed into the grass land, accounting for 81.02% of the total transformation area of water area. The main reason was that the significant decline of water area was affected by the rainfall of Songhua River. From 2005 to 2010, the average annual rainfall of Songhua River basin declined as a whole, resulting in a conversion of about 46.87 km^2 of water area into the grass land landscape with low coverage. From 2010 to 2015, there was 54.38 km^2 of the water area transformed into other landscape types, in which 35.26 km^2 water area was transformed into Cultivated land (paddy field), and it was concentrated and distributed in the vicinity of the Hulan River at the northeast of the research area, which was caused by the high humus content of the waterfront area, the fertile soil and the fact that the water area was cultivated into Cultivated land. It shows that there is a contradiction between the water area conservation and the Cultivated land reclamation, which is necessary to balance the water area conservation and the policy of returning Cultivated land to wetland. From 2005 to 2015, the main source of construction land was Cultivated land and water area, there was 56.68 km^2 of Cultivated land transformed into the construction land, and there was 15.62 km^2 of water area transformed into the construction land.

Table 2. The ecosystem transition matrix in Songbei District.

Year	Type	Cultivated land	Wood land	Grass land	Water area	Construction land	Unusd land
2005-2010	Cultivated land	467.45	1.85	11.03	5.23	24.45	6.60
	Wood land	1.24	1.51	0.08	2.38	0.13	--
	Grass land	13.71	0.48	23.21	0.05	0.93	0.16
	Water area	1.67	1.52	46.87	38.01	7.79	--
	Construction land	13.60	0.09	1.49	0.36	32.23	0.37
	Unused land	3.12	--	--	33.42	0.48	1.78
	Cultivated	454.78	0.36	4.08	2.93	36.44	2.20

	land						
2010-2015	Wood land	0.35	3.45	0.13	0.00081	0.00081	1.52
	Grass land	10.47	0.00004	29.64	4.85	1.45	36.27
	Water area	35.26	--	--	25.06	8.40	10.72
	Construction land	3.29	0.0005	0.004	2.04	60.19	0.49
	Unused land	5.06	--	0.52	0.34	1.92	1.06
	Cultivated land	439.80	2.01	8.67	5.92	56.68	3.56
2005-2015	Wood land	3.61	1.51	0.08	0.02	0.13	--
	Grass land	12.92	0.21	23.84	0.12	1.28	0.16
	Water area	9.16	--	--	25.92	15.62	45.15
	Construction land	11.75	0.09	1.33	0.41	34.18	0.38
	Unused land	31.98	--	0.46	2.83	0.52	3.01

3.3. Analysis of Dynamic Change of Landscape Pattern

3.3.1 Dynamic Analysis of Landscape Pattern at Type Level. (1) Landscape fragmentation index Patch density (PD) refers to the number of patch per unit area, which can reflect the fragmentation degree and spatial heterogeneity degree of landscape and is proportional to the fragmentation degree of landscape [15]. Largest patch index (LPI) is the proportion of the largest patch to the total area of the landscape in each type, which is a simple index to measure the dominance of each type of landscape [14,16]. It can be seen from Table 3 that the PD of wood land and construction land decreased between 2005 and 2015, the PD of other landscape type showed increasing trends while the LPI presented a decreasing trend, which indicated that the fragmentation degrees of Cultivated land, water area, grass land and other landscape types were enhanced in different degrees. In different time periods, the patch density of the Cultivated land was extremely small, and the largest patch index was far greater than the other types, which indicated that the Cultivated land was the landscape type with the largest area and the best connectivity in Songbei District. Besides, the fragmentation degree of water area landscape was the most obvious, the LPI decreased from 7.9049% in 2005 to 1.4064% in 2015, the AREA-MN decreased from 3180.0000 km2/patch in 2005 to 125.3973 km2/patch in 2015, which indicated that the area covered by water area decreased largely, the river became fragmented, and the landscape fragmentation was serious. Contrary to the changing trends of other landscape types, the construction land PD decreased, while the LPI and AREA-MN increased significantly, LPI increased from 0.3395% in 2005 to 1.1154% in 2010, which had reached 6.8865% in 2015, the AREA-MN increased from 55.8202 km2/patch to 79.3735 km2/patch and 141.1200 km2/patch correspondingly. Through analysis, it can be found that relying on the abundant natural resources in the area beside the river bank, the construction land patch in the research area tended to grow contiguously, which resulted in the decrease in the patch density of construction land and the significant increase in the largest patch index. The results indicated that the urbanization speed in the area beside the river bank was accelerated, the human activities were enhanced, the expansion of construction land affected the landscape pattern change of water area to a certain extent, which may lead to the fragmentation of the water area landscape and leave a severe challenge for the water ecological system.

(2) Landscape shape index The shape of patch should have a obvious decisive effect on the function and ecological effect of landscape. Generally speaking, the more complex the patch shape, the higher the heterogeneity degree will be [12,17]. To a certain extent, the landscape shape index (LSI) can reflect the shape complexity degree of patch, the larger the value, the more complex the shape of patch will be. It can be seen from Table 3 that the LSI of construction land, Cultivated land and water area were significantly higher than that of other landscape elements, which indicated that the patch shape may be more complex and the tortuosity may be more higher. Compared with 2005, the LSI of

wood land and construction land in 2015 decreased slightly, and the LSI of Cultivated land, grass land, water area as well as Unused land increased slightly, which indicated that the shapes of wood land and construction land were gradually tending to be square under the influence of human activities, the shape became more simple and regular, the patch similarity became higher, the shapes of Cultivated land, grass land and Unused land tended to be irregular, and the landscape heterogeneity degree became higher correspondingly.

(3) Landscape Separation index Patch segregation index (SPLIT) refers to the description of the dispersion degree of the spatial distribution of different patches in a certain landscape type. It can be seen from table 3 that the SPLIT of Cultivated land was the minimum, and the change was extremely small, which indicated that the Cultivated land had the best landscape connectivity and the effect by human activities was relatively small. Contrary to the Cultivated land, the separation degree of wood land was extremely high and grew rapidly, the SPLIT of wood land increased from 72065.1525 in 2005 to 425184.4000 in 2015, which indicated that the human activities and other factors had great impacts on the distribution of wood land, and that the phenomenon of destroying forest resources still existed, such as cutting down tree and reclaiming forest land. If these phenomena were not timely contained, the wood land resources in Songbei District would face a serious impact. The SPLIT of grass land, water area, Unused land showed varying degrees of increases, which indicated that the connectivity of grass land, water area and other landscape patches decreased. Contrary to the above landscape type changes, the SPLIT of construction land continued to decrease. From 2005 to 2015, the construction land decreased from 11745.4254 to 199.0005, which indicated that the construction land presented a contiguous growth trend and the patch connectivity was enhanced. The reason might be that the “12th Five-Year” was the fastest five years of urban construction of Songbei District, which had finished a total infrastructure investment of 28 billion and 300 million yuan. Besides, only the Science and Technology Innovation City had finished the total infrastructure investment of 12 billion and 400 million yuan. In addition, the Wanbao Avenue, Matsuura Avenue, Riverside Landscape Avenue, and other urban trunk road networks were constructed, the “three vertical and three horizontal” road traffic network was formed, the connectivity between patches of construction land was increased.

Table 3. Landscape pattern index from 2005 to 2015 at type level.

Landscape index	Year	Cultivated land	Wood land	Grass land	Water area	Construction land	Unused land
Patch density PD	2005	0.0067	0.0108	0.0256	0.0040	0.1199	0.0054
	2010	0.0081	0.0121	0.0337	0.0189	0.1118	0.0148
	2015	0.0094	0.0094	0.0269	0.0391	0.1010	0.0148
Largest patch index LPI	2005	68.9137	0.3395	2.1339	7.9049	0.3395	4.5102
	2010	67.0223	0.0970	4.8012	5.0921	1.1154	0.3395
	2015	68.0407	0.0970	1.0669	1.4064	6.8865	3.2008
Average patch size AREA-MN	2005	10317.6000	67.5000	208.4211	3180.0000	55.8202	909.0000
	2010	8334.0000	44.0000	338.4000	555.4286	79.3735	91.6364
	2015	7328.5714	41.1429	165.6000	125.3973	141.1200	464.7273
Landscape shape index LSI	2005	6.4474	3.0000	5.7143	2.8788	10.0000	3.2857
	2010	6.8933	3.0000	5.6774	5.7000	9.5714	3.6364
	2015	6.9342	2.6667	5.7500	7.0952	8.6286	4.2500
Average	2005	1.0560	1.0101	1.0267	1.0438	1.0102	1.0392

patch fractal dimension FRAC-MN	2010	1.0353	1.0067	1.0385	1.0291	1.0120	1.0180
	2015	1.0468	1.0073	1.0351	1.0275	1.0122	1.0338
Patch separation index SPLIT	2005	2.1056	72065.1525	1649.2801	115.6304	11745.4254	489.4491
	2010	2.2262	283456.2667	377.3714	254.3882	2867.0560	36653.8276
	2015	2.1598	425184.400	5002.1694	3630.9513	199.0005	733.5825

*3.3.2 Dynamic Analysis of Landscape Pattern at Landscape Level.*It can be seen from Table 4 that the patch number (NP) and patch density (PD) increased were gradually growing, the largest patch index (LPI) and the average patch size (AREA-MN) were generally decreasing rapidly as a whole from 2005 to 2015, with the acceleration of the urbanization process of Songbei District. From 2005 to 2015, the LPI decreased from 68.9137% to 68.0407%, the AREA-MN decreased from 579.9375 km^2 to 498.2013 km^2, which indicated that the number of large patch in the research area decreased, the number of small patch in the research area increased, the biodiversity decreased, and the landscape developed towards a single direction.

From the perspective of structural complexity, the landscape shape index (LSI) increased from 6.7967 in 2005 to 7.7473 in 2015, which reflected the complex trend of the patch shape of the landscape. Besides, the fractal dimension can reflected the natural degree of landscape from the perspective of patch shape complexity. In general, the bigger the fractal dimension, the smaller the interference on patch, and the greater the natural degree will be [18]. It can be seen from Table 4 that the average patch fractal dimension (FRAC-MN) was relatively stable and its value was relatively small. From 2005 to 2015, the FRAC-MN decreased at first and then increased, which decreased generally from 1.026 in 2005 to 1.0191 in 2010 and then increased to 1.0212 in 2015, which indicated that the landscape patch had been interfered by the human with high intensity.

The landscape aggregation index (AI) increased with the accelerating urbanization, which decreased from 77.8661 in 2005 to 73.8717 in 2010 and then decreased to 73.3780 in 2015, which was similar to the change trends of PD and AREA-MN. Moreover, it can be seen from different aspects that the landscape connectivity in Songbei District decreased, the spatial distribution of landscape element tended to be uniform, and the fragmentation degree increased.

Shannon diversity index (SHDI) can reflect the number of landscape types and abundance as well as heterogeneity degree of patch in the landscape. It can be seen from Table 4 that the landscape richness remained unchanged from 2005 to 2015, while the Shannon diversity index (SHDI) had been increasing. It indicated that the increase of landscape diversity was caused by the increase of the uniformity of the landscape type in the spatial distribution, which further indicated that the urbanization process increased the intensity of land use.

Table 4. Landscape pattern index at landscape level from 2005 to 2015.

landscape index	Year		
	2005	2010	2015
Patch number NP	128	148	149
Patch density PD	0.1724	0.1994	0.2007
largest patch index LPI	68.9137	67.0223	68.0407
Average patch size AREA-MN	579.9375	501.5676	498.2013
Average patch fractal dimension FRAC-MN	1.0261	1.0191	1.0212
Landscape shape index LSI	6.7967	7.6484	7.7473

Landscape aggregation index AI	77.8661	73.8717	73.3780
Shannon diversity index SHDI	1.0375	1.0512	1.0754

4. Conclusion and Discussion

In support of remote sensing and GIS technology, through the analysis of the Songbei landscape pattern change characteristics and causes. Combined with the process of urbanization in China, the destruction of the industrial revolution and traffic revolution on the area beside the river bank of this city, it is not difficult to find the following problems.

(1) The rapid urbanization accelerated the reconstruction of landscape pattern. The urbanization process had brought about tremendous change to the Songbei District, which directly leaded to the raising trend of the patch number of the landscape in the research area. In addition, the conversion between different landscape types became more frequent and the structural change turned out to be intense. Besides, the construction land occupied the cultivated land with large area, the water land was developed into paddy field, and the water landscape experienced a large area of atrophy.

(2) The trend which the landscape pattern changed from “self construction” to “being constructed” was significant. Before 2005, the landscape space in the research area was mainly the cultivated land, water area and grass land. The spatial form and distribution of each landscape element were more natural. The construction land was distributed evenly in the research area with a point distribution, the effect of human planning force was relatively small and the “self construction” was the mainly evolution of landscape pattern. However, the influence of human planning power on the evolution of urban landscape pattern has been reflected in more aspects with the developments of a series of human economic activities since 2005.The whole landscape has been developing towards the directions of fragmentation and regularization and the “being constructed” is the mainly evolution of landscape pattern nowadays.

(3) The ecological protection and humanized planning in the area beside the river bank still need to be strengthened. The sensitivity of ecological environment in The new area beside the river bank requires the increase the conservation of the green space and the blue space. Based on the main influencing factors of landscape pattern evolution in Songbei District, it is recommended to develop ecological planning, slow down the speed of urban expansion, promote the industrial structure, improve the intensive use of the urban land, change the economic growth mode, delineate the ecological protection red line, perfect the regulatory policy system and other means to realize reasonable regulation of the urban growth boundary of Songbei District and the open space along the Songhua River coast and to achieve the economic, environmental and social coordination, with the help of current “Urban Growth Boundary” (UGB) that is popular in the foreign country, the green corridor, smart growth and other management policies.

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