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Analysis on dynamic Characteristics of landscape patterns in Hailer and around areas

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Abstract. This paper analyzed the spatial-temporal dynamic changes of landscape patterns in Hailer and around areas. Firstly, landscape patterns types of research area were divided into water, sand, farmland, city and grassland based on remote sensing images of 1986, 1991, 1996 and 2001 and field investigation. Then the grassland was classified into higher coverage grassland, high coverage grassland, medium coverage grassland and low coverage grassland by Normalized Difference Vegetation Index. Finally, the spatial-temporal dynamic changes of above-mentioned eight kinds of landscape patterns were analyzed using landscape ecology principle. The results indicated that human activities intensified significant from 1986 to 2001 in research area. The area of grassland landscape decreased quickly, and the fragmentation extent intensified. The dominant landscape in research area changed from higher-high coverage grassland to medium-low coverage grassland. The expansion of sand landscape is obvious in periphery of road, city and farmland. The grassland vegetation degenerated seriously. Fragmentation of city landscape lightened, and city landscape patches tended to decrease and centralized. Economy development pattern of research area is in a stage that is transforming from extensive pattern to intensive urbanization pattern.

Keywords: Landscape patterns, Hulunbuir, Spatial-Temporal Dynamic

1 Introduction

Landscape spatial patterns are strongly connected with dynamic procession (Wu Jianguo et al., 2001; Nagendra H et al., 2006). Biologic factors, abiotic factors and human factors drive landscape patterns spatial-temporal evolution together and restrict development direction of ecological process. Analysis on landscape patterns spatial-temporal evolution can open out driving mechanism and development trend of ecological process (Su Y et al., 2005; Wu R et al., 2002; Huang Qing et al., 2007; He Chunyang et al., 2001; Zhang Yili, et al., 2006). In the study of grassland degeneration, analysis on the landscape patterns spatial-temporal evolution makes for understanding relations between landscape pattern and grassland degeneration process and provides scientific foundations on grassland ecological system management and recovery(Wang Hui et al., 2006; Wang Mulan et al., 2007; Wang Mulan et al., 2007). So many experts and scholars devote themselves to studying landscape patterns spatial-temporal evolution in grassland deterioration process. But most of them focus on highly degraded grasslands. Their natural habitats are not good and they are very easy to be disturbed by outside environment (Li Yuechen et al., 2006; Cao Chengyou et al., 2006; Tao Weiguo et al., 2007; Chen quangong et al., 2007; Chen Quangong et al., 1998; Wang Qian et al., 2007; Li Jianping et al., 2006; Wu Yunna et al., 2000; Liu Xuelu et al., 2000; Zhang Tao et al., 2007;). So almost nobody studies meadow steppe grassland and their ecology recovery functions are very good.

Hulunbuir grassland is one of the grasslands which are conserved most completed (Pan Xueqing et al., 1992). It has unique location features and typical ecological system features and advanced pasture animal husbandry production and management methods. At the same time, it is an important husbandry manufacturing base in northern China fescue grassland (Lo Bo et al., 1997; Lu Xinshi et al., 2002). But since the 1980s, under pressures of economy development and accretion of population, area of farmland and towns has been increasing rapidly in Hulunbuir grassland and degeneration tendency is still very serious. Vegetation productivity has fallen significantly. Sand expands promptly. Landscape spatial pattern changes violently. Especially Halaer area and surrounding area are typical representing regions in which human actions influence most strongly (Liu Dongxie et al., 2007; Komatsu Y et al., 2005; Zhao Huiying et al., 2007; Zhang Deping et al., 2007; Ma Yuling et al., 2004; Nie Haogang et al., 2005). So association study on intra-regional landscape spatial pattern has important academic value and useful efforts in Hulunbuir grassland ecological system management and recovery (Ren Jizhou et al., 1998).

2 Material and Method

2.1 Survey Region Overview

Hulunbuir grassland is located in the west of Daxinanling and from east to west distributed regularity. It spans forest steppe, meadow steppe and steppe. It is one of

potential grass yield and optimal herbaceous regions in Inner Mongolia grassland. We selected central region of Hulunbuir grassland as survey region including Hailer, Old Barag Banner, parts of Evenk Autonomous Banner and the whole area is 3160.82km². In survey region, hydrothermal condition is very good and it belongs to temperate continental climate. Hailer River and Yimin River mixes here. There are abundant water resource and 110 days frost free period. Mean annual temperature is -2°C. The soil is mainly chernozem. The area of farmland is very large. Main land types include city, farmland, grassland, sand and water. It has convenient transportation and rich economies. It also is population accumulation area in Hulunbuir grassland. Especially Hailer is political, economical and cultural centre and main resources collection and distribution point of Hulunbuir. It also is the point of human action maximum intensity region in Hulunbuir grassland.

2.2 Remote sensing data analysis

The selected Data is three terms 1/4 view LandSat-5 TM data and one term 1/4 view LandSat-7 ETM data from earth station of Chinese Academy of Sciences.

Tab. 1 The parameters of remote sensing data

Number	Orbit	Imaging Time	Satellite	Average Cloud
1	123/25	1986.8.6	LandSat5	<10%
2	123/25	1991.8.4	LandSat5	<10%
3	123/25	1996.7.16	LandSat5	<10%
4	123/25	2001.7.22	LandSat7	<10%

Because the above data belongs to primary production, we must use Erdas Image software to adjust images and registration error is controlled in 0.5 pixel. At the same time, we transferred projection to Albers Equal Area projection (the first and second normal latitude and central meridian are: 25、 47、 105) .

Based on secular field study in survey region and combined with supervised classification methods, we used Erdas Image software to interpret the images and divided to water, sand, farmland, city, higher coverage grassland, high coverage grassland, medium coverage grassland and low coverage grassland. And the grassland was classified by Normalized Difference Vegetation Index (Tian Qingjiu et al., 1998). NDVI vegetation indexes of higher coverage grassland, high coverage grassland, medium coverage grassland and low coverage grassland are separately (0,0.25]、 (0.25,0.5]、 (0.5,0.75]、 (0.75,1]. At last, ArcGIS was used to make 1986、 1991、 1996、 2001 landscape pattern distribution maps and the results as shown in the figure 1-4.

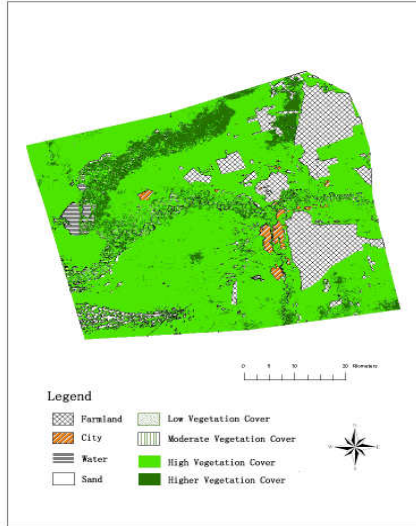


Fig.1 The distribution map of the research area landscapes, 1986

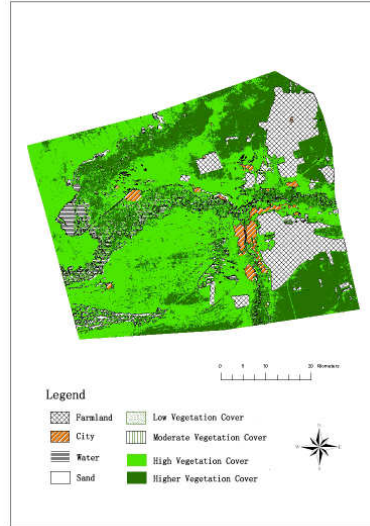


Fig.2 The distribution map of the research area landscapes, 1991

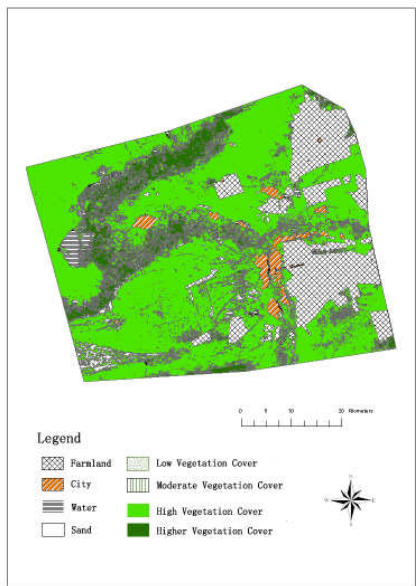


Fig.3 The distribution map of the research area landscapes, 1996

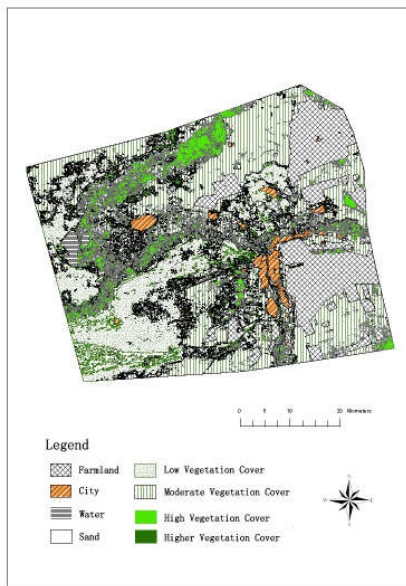


Fig.4 The distribution map of the research area landscapes, 2001

2.3 Selection of Landscape indicators

Landscape indicators can highly condense landscape pattern information and reflect structure making up and spatial configuration features. According to features of survey region, landscape indicators selected not only patch area, patch quantity such

basic parameters, but also landscape area proportion, patch density and the largest patch index.

1. Proportion of landscape area: Patches area of a type landscape accounts for the whole area, and it indicates incidence of this type patches in landscape. The formula is

$$\text{PLAND (\%)} = \frac{\sum_{j=1}^n a_{ij}}{A} (100)$$

a_{ij} : the area of j patch in i landscape; A : whole area.

2. Patch Density: ratio of patches quantity to area in a type landscape and it indicates different type landscape patches fragmentation degree and the whole landscape fragmentation degree. The formula is

$$\text{PD} = \frac{N_i}{A} (1000000)$$

A : whole area; N_i : patches quantity in i type landscape; unit: each/ km²

3. Large patch indicator: ratio of the largest patch area to whole landscape area and it indicates species richness and diversity. The formula is

$$\text{LPI (\%)} = \frac{\max(a_i)}{A} (100)$$

A : whole area; $\max(a_i)$: the largest patch area in i^{th} type landscape.

2.4 Land utilization conversion ratio calculation

$$K = \frac{U_b - U_a}{U_a T} 100\%$$

Use land utilization conversion ratio formula to calculate season year dynamic fluctuation velocity between types of landscape in survey region. In above formula, K is a sort of land utilization type dynamical degree in T timeslot; U_b and U_a are separately a sort of land utilization type quantity in childhood studies and final stage. T is the length of study period and the unit is year to express annual percentage change of a sort land utilization type .

3 Results Analysis

3.1 Land utilization conversion ratio calculation

According to 1986、1991、1996、2001 landscape type distribution maps, Fragstats was used to extract landscape indices and the results as shown in table 2.

Tab. 2 Landscape index of research area, 1986,1991,1996,2001

Year	Landscape Index	City	Sand	Farmland	Water	Low Vegetation Cover	Moderate Vegetation Cover	High Vegetation Cover	Higher Vegetation Cover	Research Area
1986	CA(KM ²)	42.08	65.23	440.51	83	0.86	25.43	2164.2	342.32	3163.63
	PLAND(%)	1.33	2.06	13.92	2.62	0.03	0.80	68.41	10.82	100
	NP(个)	50	1187	42	2131	174	3308	5379	7136	19407
	LPI(%)	0.33	1.07	5.02	0.60	0	0.05	32.72	4.89	32.72
	PD(个/KM ²)	0.02	0.38	0.0133	0.68	0.06	1.05	1.70	2.26	6.16
1991	CA(KM ²)	65.11	86.24	398.98	120.54	0.6	10.35	1546.05	935.76	3163.63
	PLAND(%)	2.06	2.73	12.61	3.81	0.02	0.33	48.87	29.58	100
	NP(个)	38	2130	42	2940	91	11597	9922	1324	28084
	LPI(%)	0.77	0.32	5.22	2.21	0	0.01	20.92	5.23	20.92
	PD(个/KM ²)	0.01	0.67	0.01	0.93	0.03	3.67	3.14	0.42	8.88
1996	CA(KM ²)	70.79	86.33	483.81	66.83	0.59	18.60	2081.86	354.82	3163.63
	PLAND(%)	2.24	2.73	15.29	2.11	0.02	0.59	65.81	11.22	100
	NP(个)	29	3587	36	1210	69	3098	4700	6363	19092
	LPI(%)	1.10	0.52	6.48	0.59	0	0.04	31.52	4.83	31.52
	PD(个/KM ²)	0.01	1.13	0.01	0.38	0.02	0.98	1.49	2.01	6.03
2001	CA(KM ²)	71.54	141	492.31	58.43	726.28	1380.21	287.35	6.51	3163.63
	PLAND(%)	2.26	4.46	15.56	1.85	22.96	43.63	9.08	0.21	100
	NP(个)	34	5847	57	1367	9114	9054	4078	527	30078
	LPI(%)	1.22	1.03	6.28	0.57	11.48	13.66	4.26	0.03	13.66
	PD(个/KM ²)	0.01	1.85	0.02	0.43	2.88	2.86	1.29	0.17	9.51

Note: CA (Class Area):The sum of the areas of all patches of the corresponding patch type. NP(Number of Patches) : The number of patches of the corresponding patch type.

From landscape area changes in table 2, area of every type landscape has wider fluctuation. Compared with 1986, landscapes of city, sand, farmland, low coverage grassland and medium coverage grassland expanded quickly and the expanded areas separately are 29.46、75.77、51.8、725.42、1354.78 km². At the same time, landscapes of water, high coverage grassland tended to reduce and the reduced areas separately are 24.57、1876.85、335.81km². In the mass, the whole area reduced 132.46km².

From landscape fragmentation features, compared with 1986, in 2001 patches quantity increased 54.99%, the largest patch area reduced 58.24% and patches density increased 55%. The landscape fragmentation degree increased significantly. But landscape species richness and diversity decreased significantly. Especially grassland landscape fluctuated intensely and weakness species increased in grassland community. A mount of poisonous plants started to emerge. The leading landscapes changed from higher and high coverage grasslands to medium and low coverage grasslands.

3.2 Landscape type area percent conversion

According to landscape type areas in different period in survey region in table 2, took advantage of land utilization percent conversion formula to calculate annual land utilization percent conversion (table 3).

Tab. 3 The rate of dynamic changes of landscape types area in survey region. Unit: %

Type of Land	$K_{1986-1991}$	$K_{1991-1996}$	$K_{1996-2001}$	$K_{1986-2001}$
City	10.95	1.74	0.21	4.67
Sand	6.44	0.02	12.67	7.74
Farmland	-1.89	4.25	0.35	0.78
Water	9.05	-8.91	-2.51	-1.97
Low Vegetation Cover	-6.05	-0.33	24599.66	5623.41
Moderate Vegetation Cover	-11.86	15.94	1464.10	355.17
High Vegetation Cover	-5.71	6.93	-17.24	-5.78
Higher Vegetation Cover	34.67	-12.42	-19.63	-6.54

From annual land utilization percent conversion in table 3, from 1986 to 2001, in the fifteen years areas of city, sand, farmland, low coverage grassland and medium coverage grassland expanded quickly, especially low and medium coverage grasslands. On the other hand, areas of water, higher and high coverage grasslands reduced significantly. On the whole, the grassland degeneration trend was very obvious. Especially from 1996 to 2001, medium and low coverage grasslands expanded dramatically and annual expanded areas account to 14 to 245 times. On the other hand, areas of high and higher coverage grasslands deduced obviously but sand expanded quickly. Grassland vegetation condition deteriorated sharply.

3.3 Landscape type Spatial Transformation

According to 1986 and 2001 landscape type distribution maps in survey region, ArcGIS software was used to extract land utilization transformation matrix (table 4).

Tab. 4 Transformation matrix of landscape types in research area, 1986-2001 Unit: km²

landscape type \ landscape type	City	Sand	Farm land	Water	Low Vegetation Cover	Moderate Vegetation Cover	High Vegetation Cover	Higher Vegetation Cover	1986 year
City	36.98	0.47	0.07	0.24	2.40	1.78	0.10	0.00	42.04
Sand	0.66	52.17	0.06	0.19	9.01	3.15	0.02	0.00	65.27
Farmland	1.35	1.39	340.44	0.03	19.81	74.63	2.70	0.00	440.34
Water	0.14	2.07	0.24	42.82	3.87	15.75	17.87	0.23	83.00
Low	0.01	0.03	0.00	0.07	0.07	0.07	0.00	0.00	0.26

Vegetation Cover Moderate	0.93	5.17	0.73	1.30	9.28	6.19	0.45	0.00	24.05
Vegetation Cover High	30.40	78.75	140.38	9.22	673.5	1118.59	114.22	0.46	2165.53
Vegetation Cover Higher	1.06	1.00	10.16	4.55	8.06	160.19	151.98	5.83	342.81
2001 year	71.53	141.04	492.08	58.42	726.00	1380.36	287.35	6.51	3163.29

From landscape type spatial transformation situation in table 4, from 1986 to 2001, in the fifteen years, landscape spatial transformation was obviously and tended to reduce. There were 32.4 km² grassland landscape transformed to city accounting for 45.3% of 2001's city landscape, 84.95 km² grassland landscape transformed to sand accounting for 60.23% of 2001's sand landscape, 151.27 km² grassland landscape transformed to farmland accounting for 30.74% of 2001's farmland landscape. Besides there are 45.45% water landscape transformed to different coverage grasslands and 2.49% transformed to sand landscape.

Every grassland landscape type transformed dramatically. There was 673.5 km² higher coverage grassland changed to low coverage grassland accounting for 92.77% of 2001's low coverage grassland. And there were 1118.59km² higher coverage grassland and 160.19 km² high coverage grassland transformed to medium coverage grassland separately accounting for 81.04% and 11.60% of 2001's medium coverage grassland. There was 151.98 km² high coverage grassland transformed to higher coverage grassland accounting for 52.89% of 2001's higher coverage grassland. On the whole, grassland vegetation degenerated seriously.

3.4 Single landscape type Analysis

The city landscape area was expanding in the fifteen years and expanded 4.67% every year. The occupied area was mainly grassland and farmland. Especially after Hulunbuir city began to take out reform of economic system from 1988, city construction made great development to make city area expand quickly. From 1986 to 1991 annual city area expanded 10.95%. Besides, city landscape patches quantity and density tended to decline, but the largest patch index tended to increase obviously. Overall city landscape fragment degree declined. This condition matched very well with the actual situation that degree of urbanization had enhanced in the past 15 years in survey region.

In the past 15 years, annual farmland landscape increased 0.78% and occupied area mainly was different coverage grasslands landscape. Because strict returning cultivated land measures were taken out after broad scale land clearing from 1980 to 1986 to make farmland landscape area decreased in 1991 compared with 1986. But with the price of food crop rising, under driving of economic interest, land clearing began to ride again in survey region. Patches quantity, density and the largest patch index of farmland landscape tended to increase after 1991 to indicate that

farmland landscape tended to expand on the whole, especially the southeastern area in 2001.

Compared with 1986, the other years' water landscape tended to decrease except 1991. In a mass, water landscape area decreased 1.97% in the past 15 years. The decreased water landscape mainly changed to different coverage grassland landscapes. Besides, patches quantity, density and the largest patch index of water landscape were inclined to decrease to indicate natural habitats of grassland vegetation were inclined to deterioration.

Sand landscape area increased 7.74% annually and the occupied land was mainly higher coverage grassland accounting for 88.60% of the whole occupied area to indicate that desertification was most serious in the regions with better vegetation condition which was significantly related to human actions. In the 15 years, patches quantity, density of sand landscape increased obviously. Patches quantity and density increased 4 times in 2001 compared with 1986 especially patches quantity in sides of river channel and surrounding of city areas increased obviously. The largest patch index decreased to indicate sand landscape fragment degree strengthened. That is because people ignored to protect unsandy grassland vegetation when they supervises serious sandy region.

The grassland vegetation degenerated seriously in 2001. The first 7 months accumulated rainfalls separately are 88.2、185.7、282.9、134mm in 1986、1991、1996、2001 in survey region and 1996's rainfall is the best. But according to monitoring result of NDVI vegetation index, 1991's vegetation condition is the best and 2001's is the worst and 1986's and 1996's are almost the same. That mainly is because ever since a long time ago, the population and grazing capacity have increased too quickly and grassland utilization intensity continued to increase to make community structure occur to serious retrogressive succession and grassland lose their own ecology self-recovery function. So although the first 7 months' rainfall in 2001 substantially exceeded 1986's, a short term better outside condition can not help vegetation to recovery quickly.

4 Conclusions and discussion

4.1 Meadow steppe self ecology recovery function is limited

Grassland ecology system has definite patent ecology recovery function. Because of better natural conditions, meadow steppe has the strongest recovery function in all types of grasslands. But there are also conditions in exertion of any patent ecology recovery function. Extravagant utilization can make community structure and soil environment occur retrogressive succession and destroy material base where exertion ecology recovery patent function develop the role. Even the recovery function will be lost and grassland makes for continued degeneration. Especially Hulunbuir grassland which has a long collecting grass and barn feeding history, this utilization patterns

destroyed completeness of seed resources base and conflicted exertion of self ecology recovery function.

4.2 Jamming is the key factor in grassland vegetation degeneration

In the past 15 years, natural factors influencing grassland vegetation had not degenerated dramatically. On the contrary, compared with 1986, accumulated rainfalls of the other three years' first 7 months were far above 1986's meanly. But in the past 15 years, in survey region, population, stock capacity and utilization intensity had increased remarkably; jamming such as land clearing, road repairing, coal digging, oil extraction, crude drugs digging had become quick degeneration accelerator of vegetation condition. All of the jamming led grassland area continued to reduce and vegetation to degenerate especially sand landscape in surroundings of roads, cities and farmlands expanded remarkably. So jamming of human actions was the key factor to lead grassland ecology system deterioration.

4.3 The urbanization level increased and economy development pattern changed from extensive pattern to intensive urbanization pattern

In the past 15 years, city landscape area increased remarkably. Fragmentation of city landscape lightened, and city landscape patches tended to decrease and centralized than ever especially Hailer region. Although city landscape area increased to occupy a mass of surrounding quality grassland, economy development pattern changed from extensive pattern to intensive pattern to enhance city server function and admit to absorb more surplus manpower in other pasturing area. Especially infrastructure in recreation industry was improved and employment opportunities were increased and economy development pressure faced by grassland landscape was relieved on the whole. It is the only way leading to realizing ecology environment improvement and economy continued development.

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2. A copyright form, signed by one author on behalf of all of the authors of the paper
3. A readme giving the name and email address of the corresponding author