Analysis on Temporal and Spatial Changes of Landscape Pattern in Dalinor Lake Wetland

Yuhai Bao*,1,2,a, Suya Bao1,2,b, Yinshan1,2,c

1 Inner Mongolia key Laboratory of Remote Sensing and Geography Information Systems, Hohhot 010022, China
2 Inner Mongolia Normal University Geographical Science, Hohhot 010022, China
*abao18376@sina.com

Abstract

Using TM remote sensing images of Dalinor Natural Reserve in 1995, 2000, 2004 and 2008 as a basic information sources, the wetland landscape spatial database for Dalinor Lake was built in this paper. By analyzing spatial variation of different types of wetland landscape and landscape pattern index variation, it revealed the landscape dynamic changes of Dalinor Lake Wetland. The results showed that the grasses grassland landscape is the advantage landscape type in the Dalinor, following by lake water wetland landscape type. From 1995 to 2008, the salt marsh landscape and sandy land landscape increased continuously. While the area of artificial paddy wetland landscape, lake water wetland landscape, swampy meadow landscape and sandy woodland landscape had a reducing trend; Patch density, shannon’s diversity index and shannon’s evenness index were continue to increase. However, the largest patch index, edge density index, area-weighted fractal dimension and dominance index had a decreasing trend as a whole. It showed that the overall landscape patches developed to small type, the degree of fragmentation and regional landscape heterogeneity increasing.

© 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of Conference ESIAT2011 Organization Committee. Open access under CC BY-NC-ND license.

Key Words: Dalinor; wetland landscape pattern; landscape index

Introduction

Landscape structure is also called the landscape pattern. It is the important performance of landscape heterogeneity, reflecting the results of the variety of ecological processes at different scales[1,2], therefore, landscape research is one of the fundamental core research areas in landscape ecology[3,5]. In landscape pattern analysis, many researchers carry out the work based on natural areas or above the county level administrative region[6-10], but the researches below the county level administrative areas are
limited. Therefore, with the regional differentiation rule in the county level administrative areas for
guidance, the paper attempts to investigate the pattern differences between different types of landscape.

Daliner Lake, located in east of Inner Mongolia grass grassland region, is the second
largest freshwater lake in Inner Mongolia Autonomous Region. It is marked interannual variation of the
East Asia monsoon region, connected to Hunshandake, as well as the important water resources in
eastern Inner Mongolia[11]. The wetland plays a particularly prominent role in regulation of local climate,
water conservation, biodiversity maintenance and optimization of human living environment. Based
on 3S technology and using remote sensing image as the main data source, the paper quantitatively
analyzes the landscape pattern change characteristics of Daliner wetland between 1995-2008,
investigating the influence factors of the landscape pattern change, providing the scientific basis for the
regional eco-environmental management and desertification control.

General situation of study area

Daliner Lake (Dari Lake) is a closeness lake belonging to the Inner Mongolia Plateau arid area, located in
west of Keshiketengqi, Chifeng City, E116°26'-116°41', N43°13'-43°23'. The lake area is
about 239km², the water elevation is 1226m-1228m, and the average depth is 6.7m. It belongs
tothetemperate continental climate, the average temperature is 1°C-2°C, the annual precipitation
is 350mm-400mm, the climate is dry, sunshine hours is long, solar radiation is strong, the amount
of evaporation is greater than supply due to successive years of drought, the lake has contracted
somewhat. The lake water is supplied by the Gongeer River, Kezi River, Shali River and Haoli River, as
well as the abundant groundwater[11].

Research methods

Landscape classification.

According to the original land use classification system and the actual local situation, it is divided
into 15 landscape types, such as shrub wetland landscape, sandy woodland landscape, sandy with high
cover grassland landscape, sandy with medium cover grassland landscape, sandy with low
cover grassland landscape, river bank water landscape, rural residential area landscape, special industrial
and mining landscape, sandy landscape, salt marsh landscape, swampy meadow landscape, lake water
wetland landscape, grasses grassland landscape, artificial paddy wetland landscape, moist meadows
landscape.

Landscape pattern index selection and calculation.

Considering the actual situation of the research area and landscape type classification system, analyzing
from the landscape type level and landscape pattern level, the paper selects six kinds of index on the
landscape type level: Patch Density (PD), Edge Density (ED), the Largest Patch Index (LPI), area
weighted fractal dimension (FRAC_AM), Aggregation Index (AI), Interspersion and Juxtaposition Index
(IJI). On the landscape pattern level, it adds another four indexes: Contagion Index (CONTAG), Shannon’s Diversity Index (SHDI), Shannon’s Evenness Index (SHEI) and the Dominance index (D). These landscape pattern indexes calculations use the currently most popular landscape pattern
analysis software FRAGSTAS3.3 in international.

Results and analysis
Analysis of lake waters wetland landscape spatial variation.

The change process of the research area landscape pattern from 1995 to 2000 is shown in Table 1, during the 5 years, the more obvious change of landscape patterns are the sandy woodland landscape, sandy landscape, swampy meadow landscape, lake water wetland landscape, salt marsh landscape, grass grassland landscape and artificial paddy wetland landscape. The most obvious change of landscape pattern is artificial paddy wetland landscape, reducing 915.35 hm²; the next is lake water wetland landscape, increasing to 683.25 hm²; In addition, the sandy woodland landscape and swampy meadow landscape respectively decreased to 273.7 hm² and 626.04 hm²; sandy landscape, salt marsh landscape and grass grassland landscape respectively increased 273.70 hm², 240.01 hm², and 631.53 hm². From the dynamic degree angle, during the 5 years, the more obvious is artificial paddy wetland landscape, river bank water landscape, swampy meadow landscape and salt marsh landscape. Among them, the fastest are artificial paddy wetland landscape and river bank water landscape, respectively reducing 12.62% and 6.23% each year; swampy meadow landscape reduces 2.48% annually, salt marsh landscape increases 1.27% annually. Spatial variation of landscape pattern is shown in Figure 1(a), during the 5 years, the more obvious changes of landscape pattern is in the northeast and southwest of Dalinor lakes, artificial paddy wetland landscape changed into grass grassland landscape mainly in DongShanJingZi between Dalinor and GangGengNuoEr and nearby HalHuShu; large area of grass grassland landscape changed into salt marsh landscape nearby GongGeErYinGuoLe and SaLinGuoLe; in the east of GangGengNuoEr, south of DongShanJingZi and buffer 2, partly swampy meadow landscape changed into lake waters wetland landscape; partly salt marsh landscape and grass grassland landscape changed into lake waters wetland landscape in the Phoenix Mouth tourist area; the sandy landscape widespread increased in southwest KeLiGengGuoLe,YangSenGuoLe. Synthesizing these change trends, it is shown that Dalinor lake wetland landscape changed obviously during 5 years and tends to dry and the ecological environment deteriorates significantly, this trend fits with variation of the ecological environment in the eastern region of China at the time.

The change process of the research area landscape pattern from 2000 to 2004 is shown in Table 1, during the 4 years, the area of each landscape has changed except shrub wetlands landscape, sandy woodland landscape, river bank water landscape, rural residential areas landscape and wet meadows landscape. Among them, the more obvious change of landscape patterns are lake waters wetland landscape and artificial paddy wetland landscape, respectively reducing 1607.09 hm² and 467.28 hm², and grass grassland landscape, salt marsh landscape and marsh meadow landscape respectively increasing 891.31 hm², 494.82 hm² and 542.30 hm². With Dalinor lake wetland landscape area reduction, grass grassland landscape, salt marsh landscape and marsh meadow landscape area increased significantly. The shrinkage of the lake water provides a good water conditions for the development of swampy and grasses, so that some aquatic, wetland plants are full of nutrients and grow in large area, finally, the swampy is formed. Form the dynamic degree angle,during the 4 years, the more obvious change of landscape patterns are sandy with medium cover grassland landscape, sandy with low cover grassland landscape and artificial paddy wetland landscape, sandy with medium cover grassland landscape increases 27.27% annually, sandy with low cover grassland landscape and artificial paddy wetland landscape respectively reduces 25.00% and 21.83% annually; in addition, salt marsh landscape and marsh meadow landscape increase 3.07% annually. With the Dalinor lake wetland area reducing, salt marsh landscape and marsh meadow landscape area increased, but sandy with medium cover grassland landscape increased faster than the salt marsh landscape, which indicated that the vegetation cover in the study area has been restored. Spatial change trend is shown in Figure 1 (b), the landscape pattern in east of study area changed significantly, some lake waters wetland landscape and grass grassland landscape changed into swampy meadow landscape; some special construction land use landscape, sandy landscape, salt marsh landscape and swampy meadow landscape changed into grass grassland landscape; some artificial paddy wetland landscape changed into sandy with high cover grassland landscape in
northeastern edge area; and a new highway was built between Dalinor fish farms and SaLinGuoLe, which provides convenience for fish transportation; sandy with low cover grassland landscape changed into sandy with high cover grassland landscape in parts of Dalinor southeastern area. The change trend shows that during the 4 years, Dalinor Lake Wetland landscape changed obviously, the vegetation cover increased significantly and the ecological environment improved obviously.

The change process of the research area landscape pattern from 2004 to 2008 is shown in Table 1, the area of grass grassland landscape, lake waters wetland landscape and sandy woodland landscape reduced obviously, respectively reducing 1838.80 hm2, 1411.40 hm2 and 218.21 hm2; the area of Salt marsh landscape, sandy landscape and sandy with low cover grassland landscape increased obviously, respectively increasing 2829.53 hm2, 366.17 hm2 and 284.49 hm2; the area of other landscape did not change significantly. From dynamic degree angle, during the 4 years, the more obvious change of landscape patterns is salt marsh landscape, increasing 15.65\% annually; nextly, artificial paddy wetland landscape increases 13.21\% annually; with artificial paddy wetland landscape and salt marsh landscape increasing, lake waters wetland landscape, grass grassland landscape and swampy meadow landscape respectively reduces 1.49\%, 0.91\% and 0.48\% annually. Spatial change trend is shown in Figure 1 (c), some swampy meadow landscape, special construction land use landscape, lake waters wetland landscape and grass grassland landscape changed into salt marsh landscape in large area mainly in the surrounding of Dalinor, upstream of GongGeErYinGuoLe and SaLinGuoLe; some swampy meadow landscape, lake waters wetland landscape and salt marsh landscape changed into sandy landscape in southeast of the Dalinor, western of GangGengNuoEr and nearby the GongGeErYinGuoLe; lake waters wetland landscape changed into swampy meadow landscape in south edge and eastern parts of the Dalinor; some sandy landscape, swampy meadow landscape and lake waters wetland landscape changed into grass grassland landscape in northeast corner, southwest of the buffer 2 and northeastern and nearby of the buffer 5, but their changing area is less obvious. The change trend shows that from 2004 to 2008 the lake area Shrinked in the research area and the wetland ecological environment began to deteriorate.

Tab. 1 The change process of wetland landscape type in the study area

| Yeasr | Landscape types          | 95-00 | 00-04 | 04-08 |
|-------|--------------------------|-------|-------|-------|
|       | Width (hm2)              | Dynamic degree (%) | Width (hm2) | Dynamic degree (%) | Width (hm2) | Dynamic degree (%) |
| shrub wetland landscape | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| sandy woodland landscape | -273.70 | -0.49 | 0.00 | 0.00 | -218.21 | -0.50 |
| sandy land high cover grassland landscape | 0.00 | 0.00 | 108.20 | 0.97 | 0.00 | 0.00 |
| sandy land mediate cover grassland landscape | 0.00 | 0.00 | 72.77 | 27.83 | 0.00 | 0.00 |
| sandy land low cover grassland landscape | 0.00 | 0.00 | -58.39 | -25.00 | 284.49 | 0.00 |
| river bank water landscape | -13.39 | -6.23 | 0.00 | 0.00 | 4.93 | 4.16 |
| rural residential area landscape | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| special industrial and mining landscape | 0.00 | 0.00 | 115.00 | 1.70 | 41.96 | 0.58 |
| sand land landscape | 273.70 | 0.32 | -91.61 | -0.13 | 366.17 | 0.53 |
| Landscape Type                      | PD_1995 | PD_2000 | PD_2004 | PD_2008 | PD_2008 |
|------------------------------------|---------|---------|---------|---------|---------|
| swampy meadow landscape            | -626.04 | -2.48   | 542.30  | 3.07    | -94.50  |
| lake water wetland landscape       | 683.25  | 0.55    | -1607.09| -1.58   | -1411.40|
| salt marsh landscape               | 240.01  | 1.27    | 494.82  | 3.07    | 2829.53 |
| grasses grassland landscape        | 631.53  | 0.26    | 891.31  | 0.45    | -1838.80|
| artificial paddy wetland landscape | -915.35 | -12.62  | -467.28 | -21.83  | 35.83   |
| moist meadow landscape             | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    |

**Analysis of wetland landscape pattern**: Index variation

**Landscape index variation on landscape type level**

**Analysis of Patch Density Index and the Largest Patch Index**. Patch Density index (PD) of the study area is shown in Figure 2, patch density index of sandy woodland landscape, special construction land use landscape, sandy landscape, grass grassland landscape, marsh meadow Landscape and salt marsh landscape are larger, sandy woodland landscape in which is the largest one, reaching about 0.18. From 1995 to 2008, the PD of the sandy woodland landscape increased, which indicated that sandy woodland landscape fragmentation degree gradually increased; followed by the value of the maximum PD is the special construction land use landscape, reaching about 0.11, from 1995 to 2008, the
PD of the special construction land use landscape increased, which indicated that with the development of the level of urbanization, the human continuous development make the patche number of the special construction use landscape larger, as well as undermining the integrity of the landscape; meanwhile, the PD of sandy landscape, grass grassland landscape, marsh meadow landscape and salt marsh landscape respectively reached about 0.06, 0.044, 0.036, 0.035. Although the PD of the four landscapes fluctuated from 1995 to 2008, it showed an increasing trend in general.

Largest Patch Index (LPI) is shown in Figure 3, LPI of grass grassland landscape, lake waters wetland landscape and sandy landscape are larger, which respectively were about 42, 17.9 and 10.4, it is indicated that grass grassland landscape, lake waters wetland landscape and sandy landscape are the advantages of landscape types in the entire study area and the grass grassland landscape is the most dominant landscape type. But on the whole, from 1995 to 2008, the LPI of the main landscape types in the study area are more and more decreasing and the lake waters wetland landscape is the fastest, to the end of 2008, the LPI of the lake waters wetland landscape is close to zero, which indicated that its dominance gradually weakened, and even replaced by other landscape types, which can also explain the constantly shrinking trend of the lake water area.

**Analysis of Edge Density Index and the Area-weighted fractal dimension.** As shown in Figure 4 and Figure 5, the larger Edge Density (ED) of the study area are sandy landscape, sandy woodland landscape and grass grassland landscape, which respectively were about 18.0, 13.3 and 9.2. It is indicated that the patch edge of sandy landscape, sandy woodland landscape and grass grassland landscape are more complex, affected by human activities, while others are more simple, little affected by human activities; the FRAC_AM of shrub wetlands landscape and salt marsh landscape are larger, while lake waters wetland landscape, rural residential areas landscape and river bank water landscape are smaller, indicating that they are little affected by human activities, simple geometric shapes and rules, and the patch geometry shapes of shrub wetlands landscape and salt marsh landscape are more complex, greatly affected by human activities. In short, from 1995 to 2008, the edge density index and area weighted fractal dimension of the study area landscape are decreasing, which indicated that the patch edge of landscape types is simple and the patch shape develops regularly and simplified.
Analysis of patch Aggregation Index. There are many index to measure landscape discrete and polymerization, in the following, the paper mainly selects Interspersion and Juxtaposition Index (IJI) and Aggregation Index (AI) to analyze the entire landscape patches accumulation and dispersion degree. The changes of Interspersion and Juxtaposition Index (IJI) for the study area is shown in Figure 6, from 1995 to 2008, the IJI of the landscape types greatly affected by human activities are smaller, such as, special construction land use landscape, rural residential areas landscape, sandy with high cover grassland landscape and sandy woodland landscape, the others are larger. The IJI of shrub wetlands landscape, grass grassland landscape, swampy meadow landscape and lake waters wetland landscape are much larger, respectively reaching about 76, 69, 55 and 51, indicating that these types’ distribution are more gathered and adjacent with other types, while the IJI of the landscape types affected by human activities are smaller, and their distribution are more discrete, with a few other types of adjacent. In all landscape types, the most obvious change of the IJI are artificial paddy field wetland landscape and sandy with low cover grassland landscape, from 1995 to 2004, their IJI increased firstly and then decreased, by 2004 it was close to zero, but between 2004 and 2008, the IJI of artificial paddy field wetland landscape decreased and the sandy with low cover grassland landscape increased. In short, the IJI of artificial paddy landscapes and half natural landscapes less than the natural landscapes, and the IJI changes much more significantly than the natural landscapes.

As shown in figure 7, from 1995 to 2008 in the entire landscapes, the Aggregation Index (AI) of grass grassland landscape, lake waters wetland landscape, grass grassland landscape, river bank water landscape and shrub wetlands landscape are relatively high, which indicated that these types reunited by a few large plaque, fragmentation degree is relatively small; from the landscape types of AI changes, artificial paddy wetland landscape, salt marsh landscape, lake waters wetland landscape and sandy with low cover grassland landscape changes significantly: from 2000 to 2004, the AI of artificial paddy wetland landscape reduced significantly, while it increased between 2004 and 2008; the AI of salt marsh landscape increased between 2004 and 2008, it did not significantly changed from 1995 to 2004; the AI of river bank water landscape increased between 1995 and 2000, from 2004 to 2008, it reduced; the AI of sandy with low cover grassland landscape between 2000 and 2004 reduced significantly, from 2004 to 2008, it increased finally. These changes will certainly relate to human disturbance and natural factors (wind erosion, water erosion, etc.), which is the main reason is the entry point for future research.
Analysis of landscape pattern index on the landscape pattern level

Tab. 2  Wetland landscape pattern index of landscape level in 1995-2008

| Years | CONTAG | SHDI  | SHEI  | D     | PD    |
|-------|--------|-------|-------|-------|-------|
| 1995  | 60.2281| 1.6743| 0.6039| 2.3257| 0.5072|
| 2000  | 60.8819| 1.6420| 0.5922| 2.3580| 0.5169|
| 2004  | 58.0316| 1.6331| 0.6367| 2.3469| 0.5347|
| 2008  | 58.8382| 1.6909| 0.6244| 2.3091| 0.5793|

The landscape index of Dalinor Lake Wetland on the landscape pattern level is shown in table 2: during the study period, the Contagion Index (CONTAG) of Dalinor lake wetlands landscape is between 58 and 61, which indicated that the aggregation of this area landscape is moderate. From 1995 to 2008, the landscape Patch Density (PD) and the Dominance Index (D) increased, indicating the fragmentation degree increases and grass grassland landscape continues to enhance the advantages of the degree; Shannon’s Diversity Index (SHDI) and Shannon’s Evenness Index (SHEI) reduced, while the number of landscape types in the region did not change, indicating the proportion of the differences between landscape types is becoming larger, uneven distribution and the landscape heterogeneity increases. From 2000 to 2004, landscape Patch Density (PD), Shannon’s Evenness Index (SHEI) increased, indicating landscape fragmentation degree is increasing, distribution of various landscape types is uniform; landscape Shannon’s Diversity Index (SHDI) and Dominance Index (D ) decreased, while the number of landscape types within the region became less (sandy with low cover grassland landscape disappeared), indicating that the proportion of various landscape types in total area was re-adjusted, the advantages of grass grassland landscape started to diminish. From 2004 to 2008, the landscape Patch Density (PD) and landscape Shannon’s Diversity Index (SHDI) increased, while the number of landscape types in the region become larger (sandy with low cover grassland landscape appeared again), indicating that the landscape fragmentation degree continuously increases, the plaque composition complexity of the landscape increased; Shannon’s Evenness Index (SHEI) and Dominance Index (D) decreased, indicating that the advantages of grass grassland landscape decreased, the difference of each composition element in becomes larger, the regional landscape heterogeneity increases.

Conclusions

According to dynamic monitoring of landscape pattern in 13 years, it showed that the Dalinor Lake Wetland landscape pattern changes were as follows:

(1) The salt marsh landscape and sandy land landscape of Dalinor increased continuously, however,
the area of artificial paddy wetland landscape, lake water wetland landscape, swampy meadow landscape and sandy woodland landscape had a reducing trend. The dynamic degree of the artificial paddy wetland landscape, lake water wetland landscape and salt marsh landscape was faster than others types. These trends explained the shrinking of lake area in Dalinor Lake and deterioration trend of the local ecological environment.

(2) The patch density of Dalinor Wetland landscape were continue to increase, and the largest patch index, edge density index, area-weighted fractal dimension and dominance index had a decreasing trend as a whole. The overall landscape patches developed to small type, patch edge were more simplistic, geometry was simpler and more regular, and the human disturbances to the heterogeneity of the landscape became more evident.

(3) The shannon’s diversity index and shannon’s evenness index of Dalinor Wetland landscape were continue to increase, but the dominance index emerged decreasing trend, it showed that with the shrinking of lake area and increasing of human exploitation intensity, part of the unused land near the lake was developed as artificial paddy wetland landscape and residential areas landscape. Therefore, a number of other landscape patches was appeared in interior of unused land, which destroyed the integrity of the original unused land landscape. The patch number , the degree of fragmentation and regional landscape heterogeneity increased, and landscape was more and more controlled by the majority of plaques. It showed the intensity of human disturbance was more and more increasing.

References

[1] Ha-BinLi,Franklin J.F.in:Landscape Ecology-- The new conceptual framework of ecology, Ecology Progress.23-33 (1988),5(1).
[2] Ye-GangWu,Ha-BinLi in:Theoretical development of landscape ecology. Jian-GuoLiu editor. Notes on Contemporary Ecology. BeiJing: China Science and Technology Press.30-39(1992).
[3] Jian-guoWu,LandscapeEcology-Pattern,Process,Scale and Hierarchy. BeiJing: Higher Education Press(2000).
[4] Bo-JieBo, Li-Ding Chen, Ma Ke-Ming et al:Landscape Ecology Principles and Applications. Beijing: Science Press(2001).
[5] Gen-xuWang, Guo-dongCheng:Study on the Landscape Pattern of Desert-oasis Ecological System, A Spatial Grid Method and Its Application. Arid Zone Research.6-11(1999),16(3).
[6] Xiao Han,OuYang,Yun Zhi,Zhao Jing Zhu,et al:Analysis of landscape spatial structure in Hainan Island. Acta Ecologica Sinica.20-27(2001),21(1).
[7] Shi-Rong Zhang, Guo-ShuGong, Liang-Ji Deng,et al:Analysis of landscape spatial patterns in the hill region in the west of Sichuan Basin.Acta Ecologica Sinica.380-38(2003),23(2).
[8] Bao-quan Jia, Long-jun Ci, Xiao-hui Yang,et al:A study on the landscape pattern change of oasis in arid land. Acta Ecologica Sinica.3-40(2001),21(1).
[9] Yuan-mei Jiao,Du-ning Xiao,Ming-guoMa,et al:Comparative Research on the Patterns of the Landscapes in the Typical Oases in the Hexi Corridor ——A Case Study in the Zhangye, Linze, Gaotai and Jiuquan Oases. Arid Zone Research.81-85(2003),20(2).
[10] Jun Zhang,Cheng-hu Zhou,Mao Pan,et al:Study on the Remote Sensing Mapping of the Landscapes and Their Spatial Distribution Pattern and Change in the Yanqi Basin, Xinjiang. Arid Zone Research.86-91(2003),20(2).
[11] Su-Min Wang,Hong-Shen Dou:Lakes in China.BeiJing:Science Press.324-325(1998).