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# STUDY ON SPATIAL LANDSCAPE PATTERN OF YANTAI CITY BASED ON RS AND GIS

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**ABSTRACT**: Influenced by artificial factors, landscape pattern of Yantai City, Shandong Province changes continuously. Revealing its landscape pattern and its changing process has a practical significance for the urban development and layout. Zhifu District, Development Zone, Laishan District and Fushan District in Yantai City were selected to study the landscape pattern. Remote sensing technology was used to obtain landscape information of different periods. Under the support of Geographic Information System (GIS), the spatial landscape pattern of Yantai City was analyzed and simulated by using various special quantitative analysis models. The analysis shows that built-up area lies in the center of Yantai City, the outside is vegetable land, irrigated land, dry land, garden land and woodland.
**KEY WORDS**: landscape; remote sensing; Geographic Information System; Yantai City

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## 1 INTRODUCTION

The analysis of spatial landscape pattern is one of the cores of the study on landscape ecology (FU *et al*., 2001). City is the center of human activities, so the urban landscape pattern and this pattern's change and development are synthetically reflected by the ecological environment system of certain region, which is produced by reciprocity of nature, biological society and economic elements. The type, shape, size, quantity and spatial combination of urban landscapes are the results of different factors' interaction, and also they affect the ecological course and edge effect of the city (CHEN and FU, 1996). Utilizing the principles and methods of landscape ecology to study urban landscape pattern is the effective means to reveal ecological status and spatial variation characteristics of a city, which is significant for changing the urban ecological environment, maintaining the ecological balance, achieving the strategic objective of the coexitence of the city and the nature, and building ecological city (CHEN and FU, 1996).

The technology of remote sensing (RS) is the best technological way to track timely or obtain spatial landscape information of a city. Geographic Information System (GIS) is the most effective technological means to carry out the spatial analysis and simulation of landscape (XIU and CHI, 1999). This research combines RS, GIS and analytic models of landscape pattern together, using the strong functions of spatial analysis to simulate and display landscape distribution, and then, measures the spatial pattern of the landscape by quantitative models (FU *et al*., 2001).

## 2 GENERAL SITUATION OF THE RESEARCH AREA

Zhifu District, Development Zone, Laishan District and Fushan District of Yantai City, Shandong Province, were selected as study area (Fig.1). The study area is located in 121°02′–121°34′E and 37°14′–37°40′N. It is 47.06km long from the north to the south and 45.73km wide from the east to the west, with an area of 1045.2km$^2$. The climate of the study area belongs to sub-humid continental monsoon climate of the warm temperate zone. Four seasons are clearly demarcated and it is distinct for monsoon's advance and retreat. The precipitation of the area is relatively plentiful. The annual average precipitation is 701.1mm and the annual average temperature is

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12.6℃. There are 246 days of frost-free period a year. Mountain, hill, plain, and coast are the main physiognomic types of the area. Agriculture mainly relies on grains, fruits and vegetables. Industry mainly concentrates on the towns, while agriculture is mainly distributed in the coastal plain. Due to a large population in the area, human activities are very intense. Influenced by artificial factors, natural landscape is reducing gradually, while artificial landscape is expanding step by step. And the difference in the spatial distribution is also very obvious.


Fig.1 Location of the study area in Yantai City

## 3 LANDSCAPE INFORMATION ANALYSIS BASED ON RS

### 3.1 Information Sources

Information sources refer to the data sources that can truly and intuitively reflect the basic characteristics of landscape pattern of the study area. Digital remote sensing image is mainly adopted in this research. Airborne remote sensing information is used in the city and the area that connect the city and the countryside. The time of the photography was October 12, 1998; absolute height is 6970m, the maximum aberration is -0.005mm, the focus is 214.839mm, ground resolution is 0.1m. Because aerial photograph belongs to the central projection, there must be various aberrations. The projection data of 1:10 000 topographic map and DEM models are used to orthographic correction. Astronautics remote sensing adopts TM digital satellite images of October 1998 and September 1988. In ERDAS system, we use three-polynomial-commutation model and 1:10 000 vector maps as references to perform geometric correction, which make it have the same coordinates with aerial photograph.

### 3.2 Extraction of Landscape Information

In order to reflect surface landscape better, and raise the accuracy of landscape information extraction, different kinds of enhancements are introduced in this research to enhance remote sensing information, including principal components analysis, vegetation index models analysis, linear transform and different wavebands stack, and information fusion technique. The extraction of landscape information is proceeded in ERDAS system. By using the method of computer interpretation and visual interpretation, the following landscape types are picked up.

(1) Dry land: the tillable land mainly depending on natural precipitation instead of artificial irrigation

(2) Irrigated land: the tillable land with a good source of water and irrigation facility

(3) Vegetable land: the tillable land mainly for planting vegetables

(4) Woodland: the land naturally or artificially growing arbor or bush

(5) Orchard: including artificial nursery, orchard and artificial grassland in urban area

(6) Built-up area: including residential areas, factory and mining area, construction land and the land for special use

(7) Water area: the water formed naturally or dug artificially, for example, river, reservoir and pond

## 4 LANDSCAPE PATTERN ANALYSIS BASED ON GIS

### 4.1 Design of Landscape Database

The design of landscape database includes the designs of spatial database, attribute database and model database. Spatial database mainly includes the results of remote sensing interpretation, all kinds of enhanced remote sensing images and all kinds of vector data that come from MapInfo. These data are stored in spatial database after they are edited. Attribute database includes three classes: the first is system attribute data, namely the attributes built in the process of interpretation or vectorization, such as the area, the perimeter of a polygon and the length of a vector line; the second is the data calculated according to system data, such as, the node number of a patch, the center coordinates of a patch, the distance and the amount of two neighbor patches; the third is attribute data for users, which come from calculation according to analysis index of landscape pattern, such as shape index, ratio of inner edge, approachability, etc. Model database includes landscape fragmentation, landscape diversity and analytic model (Table 1), which are compiled by the VFP

Table 1 The analytic models of landscape pattern of Yantai City (XIAO *et al.*, 1991)

| Sequence number | Name | Model | Meaning |
|---|---|---|---|
| 1 | Shape index | $D_i=P/2\cdot\sqrt{\pi A}$ | Shape of single patch |
| 2 | Ratio of inner edge | $S=P/A$ | Edge effect of the patches |
| 3 | Segregation degree | $R_i=\frac{1}{n}\sum_{j=1}^{n}d_{ij}$ | Separation degree between patches |
| 4 | Approachability | $a_i=\sum_{j=1}^{n}d_{ij}$ | Condition of connection corridor between the patches |
| 5 | Neighborhood index | $F_{ij}=n_{ij}/N_j$ | Complexity between the patches' edges |
| 6 | Joint degree | $L_i=\sum_{j=1}^{n}\frac{A_j}{d_j^2}$ | Gathered and disperse pattern and reciprocity between the patches |
| 7 | Diversity index | $H=-\sum_{i=1}^{m}(p_i)\log_2 p_i$ | Complexity of the patches |
| 8 | Spread ability | $H_{max}=-S\cdot(\frac{1}{S}\cdot\log_2\frac{1}{S})=-\log_2\frac{1}{S}$ | Completeness degree or diversification status of the patches pattern |
| 9 | Dominance | $D=\log_2 n+\sum_{i=1}^{n}P_i\log_2 P_i$ | Degree of one or some landscape patterns predominating landscape |

Note: $P$ is the perimeter of the patch; $A$ is the area of the patch; $d_{ij}$ is the distance between neighbor patches or the distance between corridors; $n$ is the number of neighbor patches; $n_{ij}$ is the length between the $i$th and $j$th kinds of patch; $N_j$ is the total length of the edge of the $j$th kind of patch; $A_j$ is the area of patch $j$ that is the neighbor of patch $i$; $d_j$ is the edge distance between patch $i$ and its neighbor patch $j$; $P_i$ is the area ratio of basic type of the $i$th landscape; $S$ is the number of the landscape.

language according to Landscape Ecology principles, and are linked to spatial database and attribute database by definite codes.

### 4.2 Analysis of Landscape Pattern

On the basis of landscape database, we use the mathematic models of storehouse to calculate and analyze the indexes of landscape pattern of Yantai City, such as area, perimeter, area ratio, ratio of inner edge, shape ratio, segregation degree, approachability, neighborhood, joint degree, diversity index, spread ability(Table 2 and Table 3).

### 4.3 Spatial Analysis of Landscape Pattern

Spatial analysis mainly includes two aspects: the first is the analysis of index of topographic location using DEM model; the second is the visual analysis of the landscape of Yantai City using GIS tools.

By the correlation analysis between landscape and DEM, spatial distribution of various landscape patterns can clearly be understood. For example, the dry land, irrigated land and built-up area are mainly distributed in the lowland where the altitude is under 150m and the slope is under 10°. The woodland is mainly distributed in the small hill where the slope is

Table 2 Statistical indexes and eigenvalues of landscape pattern of Yantai City

| Pattern | Number of patches | Average area | Average perimeter | Area ratio | Ratio of inner edge | Shape ratio | Diversity | Spread ability |
|---|---|---|---|---|---|---|---|---|
| Dry land | 167 | 0.53 | 2.74 | 0.89 | 5.20 | 2.00 | 0.47 | 3.86 |
| Irrigated land | 6 | 2.40 | 10.12 | 0.01 | 4.22 | 1.93 | 0.46 | 4.12 |
| Vegetable land | 42 | 4.98 | 15.80 | 0.21 | 3.17 | 1.85 | 0.09 | 5.85 |
| Woodland | 53 | 3.37 | 10.71 | 0.18 | 3.18 | 1.65 | 0.44 | 4.25 |
| Orchard | 43 | 4.42 | 14.38 | 0.19 | 3.25 | 1.58 | 0.52 | 3.75 |
| Built-up area | 105 | 2.71 | 9.26 | 0.29 | 3.42 | 1.07 | 0.31 | 3.52 |
| Water area | 7 | 4.50 | 2.99 | 0.03 | 6.65 | 3.13 | 0.16 | 5.06 |

above 10°, and there is a shrink trend to higher altitude. Orchard is mainly distributed in the hill, its slope is between 5° and 10°, and its altitude is not higher than 200 meters. The distribution of the water area is constricted by the landform, which is mainly distributed in the hill where the slope is between 5° and 10°, especially near the edge of the mountain.

The spatial visual analysis of the landscape types is based on the DEM model. The fly model is constructed on the landscape pattern of Yantai City by using GIS software. We put TM satellite image (Fig. 2) onto the DEM. According to the needs of the observation, we can control the position and the angle so as to make good effect (Fig.3).

Table 3 Segregation(A), approachability(B), neighborhood(C), joint degree(D), scatter degree(E) of landscape pattern of Yantai City

| Pattern | | Built-up area | Orchard | Woodland | Dry land | Irrigated land | Vegetable land | Water area |
|---|---|---|---|---|---|---|---|---|
| | A | 0 | 1.73 | 1.90 | 0.40 | 0.11 | 2.02 | 0.00 |
| | B | 0 | 3.55 | 1.05 | 0.23 | 0.11 | 0.25 | 2.45 |
| Built-up area | C | 1 | 0.09 | 0.06 | 0.21 | 0.28 | 0.27 | 0.01 |
| | D | 0 | 0.02 | 0.23 | 0.23 | 0.00 | 0.09 | 0.05 |
| | E | 0 | 1.19 | 1.22 | 1.01 | 1.11 | 0.65 | 1.08 |
| | A | 2.77 | 0 | 4.33 | 4.26 | 3.55 | 2.27 | 3.56 |
| | B | 20.10 | 0 | 0.86 | 6.21 | 21.34 | 0.02 | 0.64 |
| Orchard | C | 0.14 | 1 | 0.26 | 0.22 | 0.15 | 0.02 | 0.04 |
| | D | 0.00 | 0 | 0.00 | 0.00 | 0.01 | 0.06 | 0.03 |
| | E | 1.19 | 0 | 0.87 | 1.09 | 1.02 | 1 | 1.01 |
| | A | 4.35 | 5.82 | 0 | 2.96 | 3.14 | 0 | 3.01 |
| | B | 4.77 | 4.31 | 0 | 0.87 | 1.11 | 0.29 | 5.35 |
| Woodland | C | 0.05 | 0.44 | 1 | 0.18 | 0.05 | 0 | 0.03 |
| | D | 0.11 | 0.00 | 0 | 0.02 | 0.23 | 0 | 0.08 |
| | E | 1.22 | 0.87 | 0 | 1.02 | 1 | 1 | 1 |
| | A | 1.68 | 4.12 | 2.53 | 0 | 4.43 | 2.35 | 2.65 |
| | B | 5.66 | 11.36 | 3.55 | 0 | 15.21 | 0.14 | 6.33 |
| Dry land | C | 0.15 | 0.32 | 0.16 | 1 | 0.12 | 0.01 | 0.03 |
| | D | 0.01 | 0.01 | 0.02 | 0 | 0.03 | 0.99 | 0.09 |
| | E | 1.01 | 1.09 | 1.02 | 0 | 0.88 | 1 | 1 |
| | A | 4.18 | 3.90 | 2.98 | 4.31 | 0 | 3.55 | 5.33 |
| | B | 8.50 | 7.02 | 2.11 | 1.05 | 0 | 0.13 | 2.23 |
| Irrigated land | C | 0.20 | 0.23 | 0.05 | 0.13 | 1 | 0.02 | 0.16 |
| | D | 0.01 | 0.01 | 0.21 | 0.03 | 0 | 0.06 | 0.00 |
| | E | 1.11 | 1.02 | 1 | 0.88 | 0 | 0.97 | 0.66 |
| | A | 4.78 | 2.36 | 0 | 2.22 | 3.29 | 0 | 1.12 |
| | B | 5.16 | 0.09 | 0 | 0.02 | 0.05 | 0 | 0.03 |
| Vegetable | C | 0.21 | 0.25 | 1 | 0.05 | 0.25 | 1 | 0.10 |
| | D | 0.56 | 1.25 | 0 | 14.34 | 0.51 | 0 | 0.88 |
| | E | 0.65 | 1 | 0 | 1 | 0.97 | 0 | 1 |
| | A | 0 | 5.32 | 3.66 | 2.13 | 6.15 | 1.03 | 0 |
| | B | 0.96 | 1.08 | 1.45 | 1.29 | 3.30 | 0.88 | 0 |
| Water area | C | 0.01 | 0.16 | 0.09 | 0.09 | 0.49 | 0.03 | 1 |
| | D | 14.12 | 6.25 | 0.47 | 0.56 | 0.02 | 0.40 | 0 |
| | E | 1.08 | 1.01 | 1 | 1 | 0.66 | 1 | 0 |

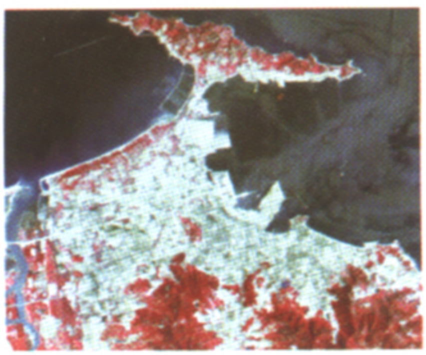

Fig. 2 TM satellite image of Yantai City(part) in 1998

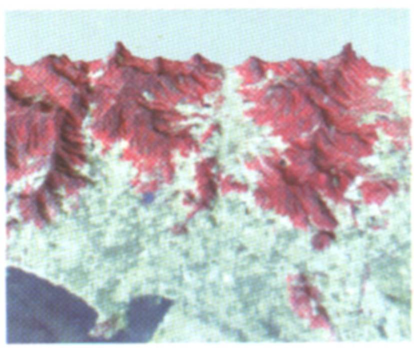

Fig. 3 Solid landscape image of Yantai City (part) in 1998

## 5 RESULTS ANALYSIS

### 5.1 Analysis of Present Situation

From remote sensing images and the results of Table 2 and Table 3, the landscape pattern of Yantai City is mainly patches. Among shape indexes, the shape index of built-up area is 1.07, near to 1, which means that the shape of built-up area of Yantai is very orderly and shows a trend of mass under the restriction of human factors; the shape index of water area is 3.13, which means that the water is entirely shaped by the topography, behaves a state of abnormal distribution. The segregation index is minimum for built-up area and dry land, which means that built-up area mainly takes up dry land, especially some villages are often constructed in the high dry land. Neighborhood index indicates the spatial combination of the different landscapes in Yantai. For example, built-up area lies in the center of Yantai, the outside is vegetable land, irrigated land, dry land, garden land and woodland. According to scatter index of landscape, the index between built-up area and vegetable land is 0.65, the index between water area and irrigated land is 0.66, which means that they are distributed very nearly in the space, and the correlation is very strong. As for diversity index, the maximum is orchard (0.52), which means that the fragmentation is very strong within the patches and the heterogeneity is great. While diversity of vegetable land is relatively low, which means that the fragmentation of vegetable land is not very great, and the heterogeneity is low. The minimum of spread ability is built-up area (only 3.52), which means that the distribution of built-up area is very extensive and disperse. While the highest is the vegetable land (5.85), which means that the vegetable land is well continuous.

## 5.2 Temporal Analysis of Landscape Pattern

Influenced by the human activities, the changes of landscape types in the research area have taken place very largely. From the satellite image of the 1988 and 1998, we can see that the areas of some kinds of landscapes increased a little, while the areas of other landscapes were shrinking. The area of built-up area increased from 138.51km$^2$ in 1988 to 284.54km$^2$ in 1998, the extent of increase reached 100.54%. The area of orchard land increased from 44.56km$^2$ to 88.10km$^2$ in the same period, the extent of increase reached 97.7%. While the area of irrigated land and dry land in the same period reduced sharply, separately from 370.49km$^2$ and 297.26km$^2$ to 190.13km$^2$ and 209.29km$^2$, the decrease extent were 48.68% and 29.59%. The increase extent of water area reached 64.06%, but the enlarged area mainly concentrated in the coastal area.

## 5.3 Problems

The first is the loss of the natural habitats. From the temporal analysis of landscape pattern, we can see that the natural habitats were largely reduced. With the development of the city, this trend will continue. The reduction of natural ecological environment will lead to the fall of stability of landscape and the aggravation of environmental pollution.

The second is the aggravation of loss of soil and water. The enlargement of built-up area has destroyed the vegetation and made the land barely and a lot of land unused, which resulted in the more and more serious loss of soil and water around the city, and led to the fragmentation of explored land, sedimentation of alluvial river-way, frequent flood and destruction of infrastructure and the security of control flood.

The third is the single landscape structure. While natural landscape reducing, the artificial landscape is enlarging gradually. The subjectivity of planning layout causes the single landscape, which bring about the instability of the city's ecological system.

The last is the reduction of landscape connectivity. This mainly behaves in two aspects: the first is the reduction of ecological connectivity. This means the channels of connection among the natural ecological environments are separated or destroyed because of the obstruction of artificial disturbance, which leads to the break of natural ecological process and reduction of landscape stability. The second is the obstacle of vision. For example, the high density of residential areas or adjoining factory or traffic trunk, which bring on limited view, pollution and noise greatly, make the reduction of viewing the landscape.

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