*Journal of Environmental Sciences* Vol. 6, No. 3, pp. 277–286, 1994 ISSN 1001–0742

# Landscape patterns and their evolutions in the suburban ecotone —A case study of the eastern suburb of Beijing

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**Abstract** — The characteristics and evolutions of the landscape patterns in the suburban ecotone are studied on the basis of landscape-ecological maps of different years derived from the corresponding aerial photos. The relationship between landscape patterns and urban economical development is analyzed. The diversity index is used to characterize the features of the landscape patterns in the ecotone and define the location of sharp change.

**Keywords:** suburban ecotone; landscape patterns; diversity index.

## 1 Introduction

The research on the changes of the urban landscape pattern is an important task of urban ecology. In the process of urbanization, the integrated effects of human activities, organism activities and the natural environment have made urban landscape patterns change much. The changes are especially remarkable in the traditional zone between city and countryside. The stability of individual landscape units and their spatial struture have changed, so have the landscape patterns. Thus distinctive landscape structure, function and evolution have developed in the ecotone (William, 1989). Studying the landscape patterns and their evolutions in the suburban ecotone is of significance in impelling the everlastingly harmonious development of city and country.

The landscape patterns and their dynamics of the last 30 years in the eastern suburb of Beijing were taken as a case study in the paper, in hope to develop a practical method to study landscape patterns at the macroscopic and dynamic levels.

## 2 Landscape feature in the research site

The research site is a small region with a total area of some 100km$^2$ in the

eastern suburb of Beijing, including Dongfang, Pingfang, Gaobeidian, Nanmofang, Jiangtai, Wangsiying and Taiyonggong townships. It belongs to the Chaoyan Administrative Area. It lies in the middle and lower part of the alluvial fan of Yongding River. With an average climate, the area has a very long history of farming and has become a major production base of grains and vegetables for the city. Because farmer exploit every last bit of land, natural vegetation has almost disappeared, and has been replaced by man-made woodlands and croplands.

In the process of urbanization in the last 30 years, economic growth and urban expansion have made the landscape patterns vary greatly. Natural expansion tends to be simple and artificial landscape to be complex. Hence, increasing economic benefits are obtained from land use.

## 3 Methods

### 3.1 Identification of landscape components

The first step was to select a research site within an area of some 100km$^2$ in the eastern suburb of Beijing, and find remote-sensing aerial photographs and topographic maps of the site for the years of 1959, 1975, 1983 and 1989 respectively. The next step was to identify these aerial photos and maps under a stereo camera on the basis of the eye explanation method. Then using the similar figure grid chart method, the task was to transfer them into landscape-ecological maps with the scale of 1:25000 (maps omitted in this paper). From these maps the following several types of landscape components were identified: non-irrigated-fields, paddy fields, irrigated farmlands, vegetable fields, woodlands, gardens, orchards, towns, industrial lands, mining lands, rural residential areas, waters and unused lands. Town, industrial lands and mining lands include urban residential areas, urban greenland and waters. Narrow corridors like railways, ditches and roadways are combined into pertinent components because they are too small to be measured on the map. With the help of a planimeter, the size of each landscape patch is measured, and the total area of these ten kinds of patches is also obtained. They can be used as primary parameters to study landscape patterns.

### 3.2 Landscape diversity index

A kind of diversity index (Shannon-Wienty index) was used to characterize the changes in use and complexity of the landscape patches in the ecotone. The diversity index is a kind of measuring index based on information theory. Its method of measurement stems from the uncertainty principle in information theory. It can be formulated as follows:

$$H=\sum_{i=1}^{n} Pi \log_2 Pi ,$$

where $H$ is landscape diversity index (its unit is a bit); $n$ is the number of landscape types; $Pi$ is the ratio of the area of $i$-th landscape type to the total area of all landscape types.

The landscape diversity index holds two implications: (1) types and numbers of landscape patches, that is abundance; (2) homogenity of landscape patches. It reflects the information derived from the landscape. The greater $H$ is the more diverse the landscape types are in the site. Hence, there are more modes of land use.

3.3 Definition of the zone of sharp change

The zone of sharp change can be located on the basis of landscape diversity indexes. The research site is divided into many grids, each with the same size of $265 \times 265 m^2$. The diversity index of each grid is calculated. The grids with the greatest diversity indexes in the east-west direction are linked into a bar band which represents the locations of sharp change in the transition from city to countryside.

## 4 Results

4.1 Landscape patterns and their evolutions in the ecotone

In general, landscape patterns are changed remarkably in three typical ways: (1) initial matrix is replaced by another matrix; (2) the relative ratio of different landscape components varies; (3) a new type of landscape components takes place in the site (Xiao, 1990).

**Table 1 The size (ha) of different landscape patches of the same year**

| Types of patches | 1959 | 1975 | 1983 | 1989 |
|---|---|---|---|---|
| Non-irrigated lands | 1699.5 | 120.0 | 102.1 | 111.4 |
| Paddy field | 326.7 | 723.4 | 663.0 | 313.9 |
| Irrigated lands | 46.9 | 2197.9 | 1667.1 | 1834.0 |
| Vegetable plots | 1554.0 | 1822.7 | 1926.8 | 1346.7 |
| Woodlands | 85.2 | 109.1 | 116.9 | 121.5 |
| Nurseries & orchards | 41.5 | 49.8 | 88.7 | 52.5 |
| Town & industrial lands and mining lands | 3230.9 | 4408.9 | 5178.1 | 6670.4 |
| Rural residences | 658.6 | 242.5 | 40.5 | 20.7 |
| Water area | 91.3 | 112 | 111.7 | 135.9 |
| Unused lands | 1868.5 | 426.9 | 134.7 | 18.5 |

Table 1 lists the size and type of each landscape patch from 1959 – 1989. It can be concluded that the landscape patterns in the ecotone have changed much over the last 30 years (Table 1).

4.1.1 The matrix of the landscape has altered

It can be observed from the landscape-ecological maps of 1951 (the map is omitted), at that time the matrix in the site was non-irrigated lands which took up a high percentage of the total area (about 90%). By 1959, non-irrigated lands decreased to a level of 39.3%. In 1975, they dropped to only 2.7% and irrigated farmlands became the matrix of the rural landscape. The percentage of irrigated farmlands went up from only 1.1% in 1959 to 49.3% in 1975. Although it declined a bit because of urban expansion and water shortage, the area of irrigated farmlands had no obvious fluctuation overall. It was the matrix until 1989. In the whole scale of the ecotone, however the area studied has been urbanizing since 1983, with town, mining lands and industrial lands as its matrix.

4.1.2 Variation of each patch

The size and quantity of different types of patches have varied over the time studied. The growth rate of each patch can be calculated as follows:

$$K=\sqrt[n]{An/A_0}-1,$$

where, $An$ stands for the area of the patch in the $n$-th years; $A_0$ is the size of the patch in the beginning year; the number of years is represented by $n$; the growth rate of each patch is calculated out and shown in Table 2.

**Table 2 The changes of patches**

| Types of patchs | 1959 – 1975 | 1975 – 1983 | 1983 – 1989 |
|---|---|---|---|
| | The changing rate per year, % | | |
| Paddy field | −5.09 | −10.96 | −13.27 |
| Non-irrigated lands | −15.30 | −0.50 | +1.47 |
| Water area | +1.30 | 0.0 | +3.31 |
| Irrigated lands | +27.2 | −3.40 | 0 |
| Vegetable plots | +1.00 | +0.70 | −5.80 |
| Woodlands | +1.54 | +0.86 | +0.64 |
| Nurseries & orchards | +1.14 | +7.5 | −8.4 |
| Unused lands | −8.9 | −13.43 | −28.00 |
| Town & industrial lands and mining lands | +1.96 | +2.03 | +2.68 |

If farming lands are defined to include non-irrigated lands, paddy fields, irrigated farmlands and vegetable plots, it can be seen that the area of farming lands has varied greatly over the last 30 years. Because of large size of unused lands, the area of farming in 1959 was 3627.1 ha. With unused lands having been reclaimed, farming lands increased, and in 1975 their area was 4864.1 ha. Since 1975, however, due to declining reclamation of unused lands and urban expansion, the area of farming lands has dropped year by year. It was 4359 ha in 1983 and only 3606 ha in 1989, less than it was in 1959. Unused lands declined sharply even in the 1970s and very little remained by 1989. This suggests the saturation of land utilization.

The size of urban landscape patches (including urban residential area), industrial lands, mining lands, and urban greenland) has been raising at an accelerated rate dur-

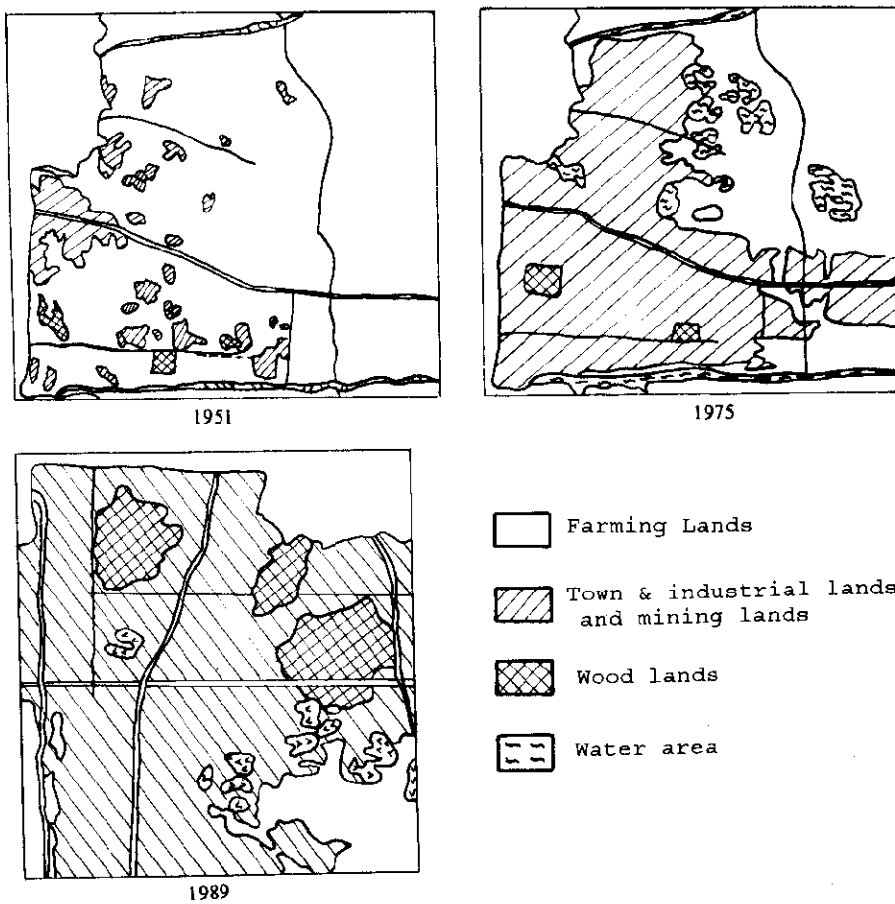


Fig.1 Changes of rural and urban landscape in some areas

ing the time studied. The area of town and mining lands was 3230.9 ha in 1959 and 6670.4 ha in 1989. If the ratio of the area urban lands to that of non-urban lands is defined as the urbanization index, then the urbanization indexes in 1959, 1975, 1983 and 1989 were 0.4755, 0.7851, 1.067 and 1.538 respectively. It shows that the city's development is mainly based on taking up farmlands, unused lands and woodlands in its periphery, as well as adjusting its own land-use structure. Fig. 1 is a group of photos taken from landscape-ecological maps, reflecting the evolutions of urban and rural landscapes in partial areas over a certain period. They illustrate the rapid expansion of the city proper in the site.

The increase of waters results from the construction of water-utilizing engineering, such as changing river beds, digging new lakes and ditches, and fishing farms in the low-lying land.

Since the 1950s, widespread planting activity has made the area of woodlands increase gradually. Especially urban greenlands have increased greatly.

The charted fluctuation of the area of paddy fields over the period assumed a peak-shape. It reached a pinnacle in the 1970s and then declined gradually so that the size in 1989 was almost equal to that in the 1950s. It can be attributed to urbanization and modification of suburb functions. For the same reasons, the areas of vegetable plots, gardens and orchards went up continuously before 1983 then dropped.

4.1.3 Improvement of transportation corridors

The corridors, which connect the country to the city, also developed significantly. Since 1959, newly built Jing-Qin, Jing-Cheng railway and Jing-Jin, Jing-Yu, Jing-Cheng roadways, plus better waterway transportation have greatly added to the links among the landscape patches and improved the overall functions of the landscapes.

4.2 The zone of sharp change and its dynamics

The suburban ecotone is the transitional zone from urban landscape whose matrix is city and mining lands to rural landscape whose matrix is irrigated farmlands, and it shares characteristics of both landscapes. In the ecotone, the effects of human activity is distinctive. New urban landscape patches disturb initial rural landscape patches, and the percentage of the size of each component varies. The matrix of the landscape also alters, but these changes are gradual and uneven. There is a zone in the ecotone which is most informative and heterogeneous, and it includes the characteristics of both the city and countryside. It is called the zone of sharp change in the ecotone. One side of the zone of sharp change is city proper, and the other side is countryside. The zone of sharp change possesses unique structural and countryside.

It has its own distinctive material flow, energy flow and species flow. It is the most active region of landscape ecology with extremely strong heterogeneity. Probing the position and dynamics of the zone of sharp change is beneficial to understand the process of urbanization and predict its developmental tendencies.

Based on the calculation and comparison of the diversity index of the landscapes, the ecotone can be outlined and the zone of sharp change can be defined roughly. The principle is that on each side of the rural and urban landscape the patterns are simple and their diversity indexes are low. In the transitional area between city and country, the landscape patterns become complex and the diversity index increases. The zone where the diversity index reaches its maximum is the zone of sharp change in the ecotone. The diversity index of each grid (265×265) in the site was calculated and then the grids which have the greatest diversity indexes in the west-east direction were linked into a bar band, which indicated the location of the zone of sharp change. Fig.2 portrays the locations of the zone of sharp change in the eastern suburb of Beijing at different times. It shows that the zone of sharp change has been pushed outward gradually because of the urban expansion over the past 30 years.

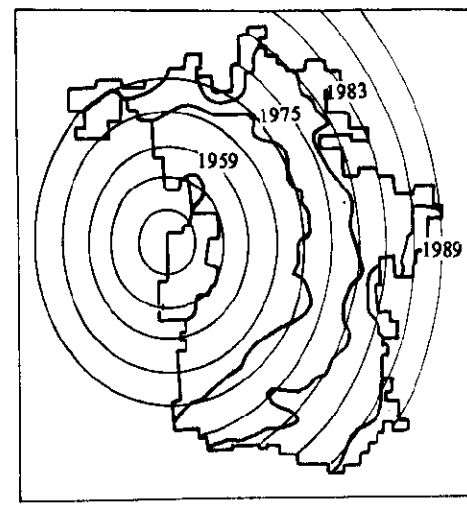


Fig.2 Sketch map of one of sharp change

**Table 3 The diversity indexes of the landscape in different years**

| Location | 1959 | 1975 | 1983 | 1989 |
|---|---|---|---|---|
| Urban area | 0.79 | 0.76 | 0.64 | 0.61 |
| Zone of sharp change | 2.81 | 2.40 | 2.14 | 1.92 |
| Rural area | 0.99 | 0.88 | 0.75 | 0.69 |

Note: The urban area landscape group includes urban residences, industrial and mining lands, urban greenland and water area

Table 3 lists the average values of the diversity indexes of city proper, the zone of sharp change and countryside in different years. It suggests that the fluctuation of the diversity indexes assumes a peak shape: those of city proper and countryside are low, and those of the zone of sharp change are high. The method of analyzing the expanding dynamics of the zone of sharp change is to divide the research site into ten clitella with the mid point of the north-south edge connecting city proper and countryside as the center point, the lengths of 1/10, 2/10, ···, 10/10 of the north-south length of the site as diameters. The clitellum where the most change occurs is the zone of sharp change. The zone of sharp change in 1959, 1975, 1983, and 1989 correspond to the second, fifth, seventh, and ninth clitellum respectively. The calculation suggests that the zone of sharp change was pushed outward at an average speed of 232.2 m/a from 1959 to 1975, 310.2 cm/a from 1975 to1983, 414 m/a from 1983 to 1989. It can be concluded that city expansion has accelerated year by year. However, the city has not expanded itself in every direction at the same speed. It has developed to Gaobeidian, Pingfang and Taiyanggong townships at the greater speed.

4.3 The relation between the evolution of landscape patterns and city development

As mentioned above, the landscape patterns in the site have changed radically over the last 30 years. The change is closely related to human activities. In order to analyze the relationship between them, several groups of curves (Fig.3) are presented to portray the fluctuation of urban expansion, economic density and population density of each township in the area including the average value of the seven township from 1970s to 1990s.

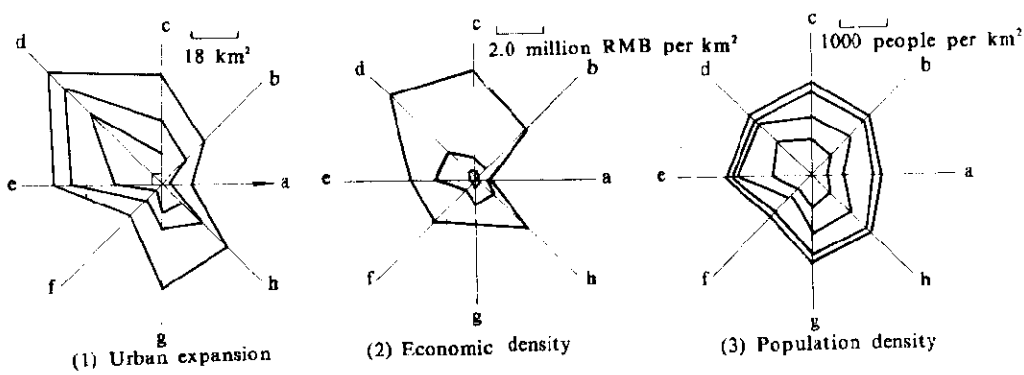


Fig.3 The trend of urban expansion economic density and population density
a. Dongfang Township b. Jiangtai c. Pingfang d. Gaobeidian e. Nanmofang
f. Wangsiying g. Taiyanggong h. average of the Chaoyang Administrative Area

Here, town and mining area is used as an indicator of urban expansion, the value of economic output (including agricultural and industrial output value, 10000 RMB Yuan/km$^2$ per unit of land) is an indicator of economic density, and the number of population per unit of area (persons/km$^2$) is an indicator of population density. Fig.3 shows that the size of city proper has been increasing all the time with an especially great speed in the three town ships of Gaobeidian, Nanmofang and Pingfang since the 1970s. City development and economic growth have caused great changes in the mode of land use and further changes in the function of pertinent landscapes. As a result, formerly rural landscapes with lower-economic density are replaced by present urban landscape with high economic density and the two kinds of landscapes assume the same developing trend. Human activities are most responsible for the transformation of landscape patterns. With urban expansion and ever increasing economic density, population density rises as well. However, the land-utilizing capacity is limited. Unused lands in the site have been almost exhaused over the past thirty years. More and more farmlands will be taken up if urban expansion continues.

The suburban ecotone is a large system composed of many patches, transportation corridors and the ecotone's matrix. Its prospective functions depend to a great extent upon the interactions and cooperation among its components, which also bring about favorable ecological cycles among city proper, suburb and countryside. Every landscape component is not only a kind of land source or form of land use, but also an important factor in maintaining the stability of the ecosystem. We should, therefore, strive to improve ecological benefits as well as economical benefits. Only when the landscape patterns of the ecotone are arranged properly can the urban and rural ecosystems develop persistently and harmoniously.

## 5 Conclusion

Landscape ecology as a subject of science has been rapidly advancing since the late 1970s, both in theory and practice (Haber, 1981; Turner, 1983).

The overall structures of the landscape will alter under the disturbance of human and natural activities, and then landscape functions will also be affected. Its energy flow, material flow and species flow will differ from before. To study the interaction of landscape patterns and functions is of great importance both in theory and practice.

The suburban ecotone between urban and rural landscapes is the zone which is greatly influenced by human activity and develop its own distinctive landscape struc-

ture, function and evolution. Regarding material production, the countryside is the region where many agricultural products (organic substances) are produced and transported to the city, and the city proper is the region where industrial products (inorganic substances) are manufactured and sold to the countryside. Within the ecotone, however, it is possible to merge the two forms of production. Solar energy is the major resource to produce organic substances in the countryside, fossil fuels are the major energy resources in the city proper. Both are utilized in the ecotone. Thus, the suburban ecotone shares characteristics of rural and urban landscapes. In particular the zone of sharp change is the center of information flow from its two sides. It is the most active region of landscape ecology with extremely strong heterogeneity. The method of defining the zone of sharp change by calculating and comparing the diversity indexes is feasible and reasonable.

As can be seen from the case studied above, the landscape patterns on the suburban ecotone of the eastern suburb of Beijing have changed dramatically over the past 30 year. The location of the zone of sharp change outlined from landscape-ecological maps is in accordance with that defined by the calculation of the diversity indexes. With the expansion of the city proper, the zone of sharp change has been pushed to the countryside gradually. In the meantime, economic density and population density have increased correspondingly. To study the history and economic growth of the movement of the zone of sharp change is helpful to predict the change of the ecotone in the future. If the process of urbanization continues within a limited region in the zone of sharp change, the mode of former landscape evolution will reoccur in the future. Thus, although one cannot definitely forecast where a special kind of landscape pattern will be, one can obtain in advance some knowledge of the whole pattern of the future landscape by analyzing the evolution of the zone of sharp change in the past decades. The finding can provide a scientific basis for city planning.

## References

Chen Changdu. Strategy research on development of ecology in China. Beijing: China Economy Publishing. 1991: 232

Haber WE, Schaller J. Center for agri pub & doc. Wagenigen, Netherlands. 1981: 316

Turner (Translated by Lin Chao). Translating Journal of Geography, 1983; 1:1

William LB. Landscape Ecology. 1989; 1(2): 113

Xiao Duning. Chinese Journal of Applied Ecology, 1990; 1(1):44

(Received March 11, 1993)