

Land Use/Cover Change Process and Driving Force Analysis in Lianyungang

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Abstract—Land use/cover change is an important issue for global environmental research. Combined with the use of GIS, this paper explores the utilities of CBERS images to analyze the land use/cover changes in the city of Lianyungang, and analyzes the driving forces by the principal component analysis. Results show that during the past 8 years, the local land use pattern has changed greatly, especially for the land types with lower economic benefits, which have been converted to those with higher economic benefits. Among them, areas of the cultivated land and saltern land decreased greatly and most of them had been transformed to construction land. The unused land converted to construction land also increased significantly. Socio-economic factors such as population, economic development and scientific technology have major effect on the regional landscape dynamics.

Keywords—land use/cover change; driving force; remote sensing; Lianyungang

I. INTRODUCTION

With the further study of global change research, scientists came to realize land cover change caused by human being's use is the main reason of global environmental change [1-2], and land use/cover change (LUCC) has become an important issue for global change research [3-7]. The coastal zone, as a typical transitional zone between land and ocean, is a multifunctional and complex ecosystem with special ecological values and potential resources, and its land use/cover changes rapidly. In different coastal areas of the world, a variety of signs show that high intensity of man's use of limited resources resulted in tremendous pressure to coastal environment, including reduced biodiversity, sea level rise, exhausted fishery, frequently natural disaster, etc. At present, the International Geosphere-Biosphere Program (IGBP) determines LUCC as one of the core research of Land-Ocean Interactions in the Coastal Zone (LOICZ).

Over the past 10 years, an increasing number of scientists have devoted their efforts into LUCC research, and coastal LUCC study makes a figure [8-11]. Along with China's rapid economic development, as the first to open the door of the coastal open cities, Lianyungang's land utilization has been improved a lot and its landscape pattern has been changed significantly. The objective of this paper is to study the spatial distribution of different

land use/cover changes in Lianyungang and to find the driving forces.

II. STUDY AREA AND MATERIALS

A. Study area

The case study area lies in Lianyungang, which is located in the northeast of Jiangsu province, China and bordered by the Yellow Sea (Fig. 1). The 900km² region lies between 119° 3' E to 119° 41' E and 34° 25' N to 34° 51' N. Name of the region roots in its beautiful coastal environment and flourishing port trade. It experiences a transitional climate from warm temperate to subtropical temperate, belonging to a humid marine monsoon climate. It has four distinct seasons, an appropriate temperature, sufficient light, and moderate rainfall. Its landscape is divided into three parts, including the eastern coastal area, the central plain area and the western hilly area. At present, it has been identified as a potential coastal city in east China for its industries, tourism and port trade.

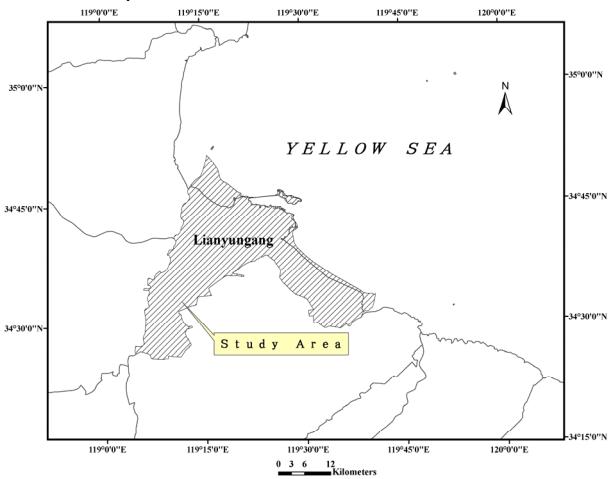


Figure 1. Study area

B. Materials

Three sets of remote sensing images were used in this paper. The main source data were CBERS images, which have been increasingly used as one important carrier for research by domestic and foreign researchers because of their higher spatial, spectral and temporal resolution

presented in a greater band width [12-15]. Three CBERS images were used to identify and monitor the regional land/cover changes, respectively acquired in 1999, 2003 and 2007, and five multispectral bands of them were utilized with the spatial resolution of approximately 20×20m. The two other sets of remote sensing images were respectively Landsat Enhanced Thematic Mapper Plus (ETM+) images (acquired in 2000) and SPOT images (acquired in 2003 and 2005). All of them were already georeferenced before and were respectively used to geometrically correct the three CBERS images by close time phase. Registration met the requirements of RMS error of not more than 0.5 pixels.

III. METHODS

Before classifying land use/cover, histogram matching was made to partially eliminate effect difference between images caused by different solar altitude or atmospheric environment. Finally, Lianyungang's digitalized administrative borders were overlaid on three CBERS images to extract regional land use/cover changes.

A. Land use/cover change range detection

Establishment of the classification system is the key process for land use/cover changes detection. Through artificial visual interpretation, three CBERS images were classified into 12 classes. Supported by GIS, regional land use/cover information during three different periods was digitalized (Fig. 2). Spatial attribute data were obtained through overlay analysis.

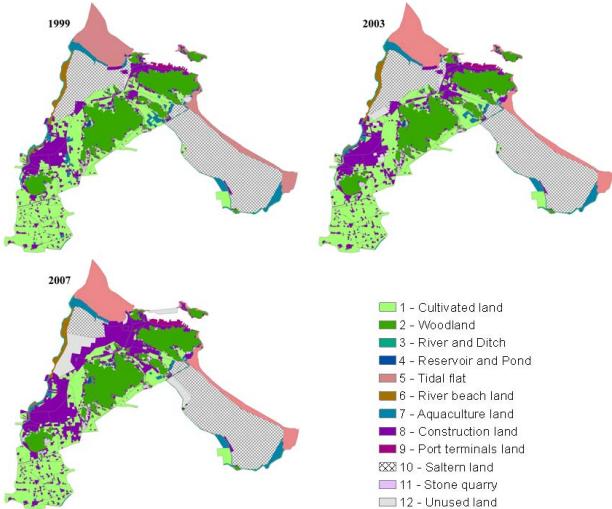


Figure 2. Land use/cover classification from 1999 to 2007

According to digitalized land use/cover maps, regional land use/cover changes range was determined. Results revealed that during the past 8 years cultivated land, woodland and saltern land had conspicuous reduction. Conversely, construction land and unused land increased greatly. Totally, change range between 2003 and 2007 was larger than that between 1999 and 2003. Cultivated land decreased 3121.53ha because of regional population pressure and urban development. Saltern land decreased 5914.85 ha because of its lower economic effect. On the contrary, construction land and unused land increased 6979.18 ha and 3525.94 ha respectively.

B. Land use/cover change speed detection

Land use/cover transfer matrix and dynamic degree index were used to delineate the characteristics of regional land use/cover changes. It is considered that transfer matrix can clearly reflect the conversion relationship between various land use/cover types, and it also can make a clear grasp of source to increase or to reduce for various types, which is useful to administrators [16]. Table 1 shows the land use/cover conversion between 1999 and 2003, and table 2 shows the land use/cover conversion between 2003 and 2007.

In both tables diagonal values represents those non-changed land use/cover types, while off-diagonal values represents those changed ones. According to these values, we found the flow direction of cultivated land and aquaculture land is mainly construction land. The reduction of woodland is due to the increase of stone quarry. Saltern land mainly converted into construction land and bared soils, which are being in the transition stage of construction land.

On the other hand, it suggests that dynamic degree index can reveal the speed and degree of land use/cover changes [17-18]. The dynamic index of single land use/cover can reflect the change range and speed of different land use/cover changes. While the dynamic index of synthetic land use/cover can delineate the degree of land use/cover changes. The dynamic index of single land use/cover was calculated by a simple formula due to the initial and the final area of different single land use/cover.

$$K = \frac{U_a - U_b}{U_a} \times 100\% . \quad (1)$$

Where K is the dynamic index of some single land use/cover during T periods, and U_a and U_b are respectively the initial area at time a and the final area at time b .

Dynamic index of synthetic land use/cover was calculated mainly considering the conversion area of different land use/cover between the initial time and final time.

$$LC = \left[\frac{\sum_i \Delta LU_{i-j}}{\sum_i LU_i} \right] \times 100\% . \quad (2)$$

Where LC is the dynamic index of synthetic land use/cover during T periods, and LU_i is the initial area of type i , and ΔLU_{i-j} is the absolute value of conversion area from type i to type j during the monitoring periods.

According to (1), we got the dynamic indexes of single land use/cover during three periods (table 3). The calculated results show that construction land, stone quarry and unused land were increasing greatly. Moreover, the increasing speed of the second period was larger than that of the first period. Conversely, cultivated land and saltern land both decreased, and the decrease speed of the second period was larger than that of the first period. According to (2), we calculated the dynamic indexes of synthetic land use/cover in two different periods, and they were respectively 4.78% between 1999 and 2003, and 11.43% between 2003 and 2007. The result again indicates that the speed of land use/cover changes from 2003 to 2007 was larger than that from 1999 to 2003.

TABLE I. LAND USE/COVER CONVERSION BETWEEN 1999 AND 2003

| Class names | 1 (ha) | 2 (ha) | 3 (ha) | 4 (ha) | 5 (ha) | 6 (ha) | 7 (ha) | 8 (ha) | 9 (ha) | 10 (ha) | 11 (ha) | 12 (ha) |
|-------------|----------|----------|--------|--------|---------|--------|---------|---------|--------|----------|---------|---------|
| 1 | 20770.98 | 46.23 | 11.05 | 4.10 | 0.00 | 0.00 | 85.84 | 1341.16 | 0.00 | 0.14 | 10.75 | 128.37 |
| 2 | 28.44 | 14650.56 | 0.00 | 4.24 | 1.23 | 0.00 | 0.00 | 91.51 | 0.00 | 0.00 | 129.57 | 0.00 |
| 3 | 27.91 | 0.00 | 996.58 | 1.37 | 0.00 | 51.55 | 8.12 | 23.11 | 0.00 | 6.91 | 0.00 | 0.00 |
| 4 | 25.77 | 19.13 | 0.00 | 243.62 | 0.00 | 0.00 | 0.00 | 6.05 | 0.00 | 0.00 | 3.36 | 0.00 |
| 5 | 0.00 | 0.00 | 0.00 | 0.00 | 9267.88 | 0.00 | 88.03 | 11.48 | 4.32 | 0.00 | 0.00 | 0.53 |
| 6 | 26.55 | 0.00 | 0.00 | 0.00 | 0.00 | 828.40 | 105.12 | 45.61 | 0.00 | 0.00 | 0.00 | 0.00 |
| 7 | 579.72 | 0.00 | 1.42 | 0.00 | 31.91 | 0.00 | 2014.65 | 60.20 | 0.00 | 0.00 | 0.00 | 163.48 |
| 8 | 261.68 | 33.88 | 8.21 | 0.17 | 0.16 | 0.00 | 0.00 | 9876.0 | 0.04 | 6.51 | 46.62 | 30.99 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 483.06 | 0.00 | 0.00 | 0.00 |
| 10 | 0.05 | 0.10 | 19.44 | 0.00 | 0.00 | 0.00 | 11.58 | 0.40 | 0.00 | 25421.61 | 0.00 | 480.99 |
| 11 | 9.26 | 26.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 6.60 | 0.00 | 0.00 | 438.49 | 0.00 |
| 12 | 0.00 | 0.00 | 0.00 | 5.75 | 0.00 | 0.00 | 8.19 | 123.64 | 24.42 | 0.00 | 0.00 | 237.88 |

Class names are consistent with that in Figure 2.

TABLE II. LAND USE/COVER CONVERSION BETWEEN 2003 AND 2007

| Class names | 1 (ha) | 2 (ha) | 3 (ha) | 4 (ha) | 5 (ha) | 6 (ha) | 7 (ha) | 8 (ha) | 9 (ha) | 10 (ha) | 11 (ha) | 12 (ha) |
|-------------|----------|----------|--------|--------|---------|--------|---------|----------|--------|----------|---------|---------|
| 1 | 18738.47 | 66.64 | 14.92 | 16.39 | 0.00 | 15.74 | 38.21 | 2694.43 | 0.00 | 1.96 | 73.31 | 70.30 |
| 2 | 9.43 | 14433.21 | 0.00 | 6.08 | 0.00 | 0.00 | 0.00 | 121.08 | 0.00 | 0.10 | 207.25 | 0.00 |
| 3 | 7.31 | 0.00 | 991.47 | 0.00 | 0.00 | 0.00 | 0.70 | 13.89 | 0.00 | 16.23 | 0.00 | 7.07 |
| 4 | 1.65 | 5.80 | 0.10 | 244.38 | 0.00 | 0.00 | 0.00 | 1.96 | 0.00 | 0.00 | 5.19 | 0.00 |
| 5 | 0.00 | 0.91 | 0.00 | 0.00 | 9119.54 | 0.00 | 65.75 | 79.01 | 0.00 | 0.00 | 0.00 | 37.75 |
| 6 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 879.94 | 0.00 | 0.025 | 0.00 | 0.00 | 0.00 | 0.00 |
| 7 | 156.20 | 0.00 | 8.11 | 0.00 | 1.92 | 0.00 | 2053.13 | 67.25 | 0.00 | 11.23 | 0.08 | 23.70 |
| 8 | 360.28 | 27.44 | 6.05 | 0.57 | 0.33 | 2.59 | 6.04 | 11151.26 | 0.00 | 3.38 | 25.52 | 2.32 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.97 | 0.00 | 0.00 | 0.00 | 583.65 | 0.00 | 0.00 | 0.00 |
| 10 | 1.45 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 2633.23 | 0.00 | 19986.43 | 0.00 | 2813.74 |
| 11 | 2.31 | 25.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.99 | 0.00 | 0.00 | 587.44 | 0.00 |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 467.69 | 0.00 | 0.00 | 0.00 | 574.55 |

Class names are consistent with that in Figure 2.

TABLE III. DYNAMIC INDEXES OF SINGLE LAND USE/COVER

| Class names | K (from 1999 to 2003) (%) | K (from 2003 to 2007) (%) | K (from 1999 to 2007) (%) |
|-------------|---------------------------|---------------------------|---------------------------|
| 1 | 2.98 | 17.33 | 13.94 |
| 2 | 0.86 | 1.48 | 2.32 |
| 3 | 7.07 | 1.50 | 8.46 |
| 4 | 13.04 | -3.22 | 10.24 |
| 5 | 0.754 | 1.94 | 2.68 |
| 6 | 12.49 | -2.06 | 10.68 |
| 7 | 18.58 | 6.80 | 24.11 |
| 8 | -12.87 | -48.84 | -67.80 |
| 9 | -21.02 | -6.44 | -28.81 |
| 10 | 1.92 | 21.30 | 22.81 |
| 11 | -30.65 | -42.94 | -86.74 |
| 12 | -160.64 | -276.67 | -881.75 |

Class names are consistent with that in Figure 2.

C. Driving forces analysis

Effects that caused land use/cover changed are complicated. Many studies revealed that these effects could be concluded from biophysical to socio-economic anyway [19]. But biophysical effects, including topography, geomorphology, soil and climate etc., were proved to have effect significantly usually in a large-scale spatial and temporal domain. In other words, those complex socio-economic factors were believed to act on land use/cover changes in a small-scale spatial and temporal domain. Therefore, to find the socio-economic factors influencing regional land use/cover changes are the main case of the solution. Results suggest that the method of principal component analysis (PCA) is an effective way for this problem. In this paper, PCA was used to examine the driving forces from a series of socio-economic statistics from 1999 to 2006. Ten variable indicators were

involved in the principal component analysis, and they were respectively year-end population (X_1), GDP (X_2), gross industrial output (X_3), consumer price index (X_4), commodity price index (X_5), agricultural output (X_6), agriculture-forestry-fisheries output index (X_7), agriculture chemical fertilizer amount (X_8), urban fixed asset investment (X_9) and number of employees (X_{10}). Correlation matrix among different variables, variance contribution, cumulative variance contribution and correlation matrix among different principal components were calculated. Results indicate that variance contribution of the first principal component accounted for 74.74%, and variance contribution of the first two principal components accounted for 88.68%. Therefore the first two principal components were sufficient to describe the effect of land use/cover changes. Equations of the first two principal components are:

$$\begin{aligned}
F1 &= 0.981X1 + 0.994X2 + 0.985X3 + \\
&0.671X4 + 0.858X5 + 0.465X6 + 0.980X7 \\
&+ 0.783X8 + 0.965X9 + 0.804X10 \\
&\quad (3) \\
F2 &= -0.091X1 + 0.039X2 + 0.108X3 - \\
&0.599X4 - 0.457X5 + 0.746X6 + 0.074X7 \\
&- 0.074X8 - 0.016X9 + 0.488X10
\end{aligned} \tag{4}$$

Equation (3) is the formula of the first principal component, where the correlation coefficient values between $X1, X2, X3, X7$ and $X9$ are relatively larger, so the first principal component could be regarded as the integrated indicators of population, GDP, gross industrial output, agriculture-forestry-fisheries output and urban fixed asset investment. Similarly, the second principal component could be regarded as the integrated indicators of the scientific technology, as the coefficient value of $X6$ is relatively larger.

According to the principal component analysis, results indicate that these indicators, which respectively are population, GDP, industrial and agricultural output, and urban fixed asset investment and scientific technology, could be concluded as the main driving forces for the land use/cover changes in Lianyungang. To summarize, population, economic development and scientific technology could be concluded as major factors which have significant effect on the regional landscape dynamics.

IV. CONCLUSION AND DISCUSSION

Results demonstrate that land use pattern have changed greatly in the past 8 years in Lianyungang. Moreover, its change range and speed between 2003 and 2007 were far larger than that between 1999 and 2003. The reason for such changes was that land types with lower economic benefits had been converted to those with higher economic benefits. Typically, the cultivated land, saltern land decreased greatly and most of them had been transformed to construction land. Those unused land, which is going to be converted to construction land also increased dramatically. In addition, by using the socio-economic statistic data, the method of principal component analysis was applied to assess the socio-economic driving forces. Based on the analysis, indubitably, population, economic development and scientific technology were suggested to be the major factors for land use/cover changes. But how to take appropriate measures to rationally adjust industrial structure and coordinate the eternal relationship between man and land would be worthy of considering and thinking for relevant government departments.

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