Study of Land Use and Land Cover Changes in the Baoan District, Shenzhen from 2000 to 2010

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***Abstract*-This paper used Landsat ETM images as the main data source, and ENVI, GIS and the mathematical statistics method (dynamic degree, land use transition matrix) to analyze spatiotemporal changes of land use and land cover in Baoan, Shenzhen, from 2000 to 2010. Conclusions were as follows. (1) The major land use in the study area was green land. Industrial and storage land experienced the largest increase among the six land classes; external transport land experienced the second largest increase. Water experienced the largest reduction among the six classes, followed by "other" land and green land. (2) Construction land experienced a slow increase, followed by a rapid increase; green land reduced rapidly between 2000 and 2005, followed by a slower reduction between 2005 and 2010. The area of water increased in the early period and decreased in the later period. (3) The increase in construction land came mainly from industrial and storage land, green land, external transport land, and other lands. The increase in industrial and storage land came mainly from construction land, green land, and other lands. The decrease in green land and water area came mainly from the expansion of industrial and storage land, construction land, other land, external transport land.**

Keywords- Land Use/Cover Change; Spatiotemporal Analysis; Baoan District; Shenzhen

I. INTRODUCTION

Many of the researches on global geophysical changes have focused on regional land use and land cover changes. Comprehensive study of these changes on the regional or local scales could provide a wealth of information for global land use and land cover changes [1-4]. In addition, land-use change is closely related to both socioeconomic development and environmental changes. Since 1978, when China initiated economic reform and an open-door policy, rapid land use and land cover changes have taken place in many areas of the country [5, 6]. It has been well documented that drastic land-use change, especially the conversion of green land for industrial, storage, or building use, has occurred in the course of environmental changes, industrialization, and urbanization throughout the country [7-10]. Regional land-use changes in the eastern developed regions of China, in particular, have received a great deal of attention [5], [11-14].

However, land-use changes in Baoan, which were outside the old Special Economic Zone of Shenzhen, have attracted little attention. Baoan serves an important economic function, as well as a pivotal role in the overall economic development strategy and design of urban functions, in Shenzhen. It is also a critical link between the Shenzhen economic radius and the mainland. Both economic development and environmental changes have strongly influenced land-use changes. In addition, as in Hong Kong, there is always a major planning challenge in determining efficient land uses in a hilly area with limited flat land [1].

This study used high-resolution remote sensing imaging (Landsat ETM images) as the main data source, and utilized the ENVI GIS and mathematical statistics method to analyze spatiotemporal changes in land use/cover in Baoan, Shenzhen, from 2000 to 2010.

II. STUDY AREA

A. *Natural Environment*

Baoan District is located in the South China Sea, Guangdong, and is one of the seven districts of Shenzhen City. It is located at longitude 113°46′ to 114°37′ E, latitude 22°27′ to 22°52′ N. The total land area is 733 km^2 (accounting for 37% of the total land area of Shenzhen), with a coastline length of 30.62 km. It is connected to the Pearl River estuary in the west, the Shenzhen Special Economic Zone in the south, Dongguan City in the north, and Mirs Bay in the east, near the New Territories and Yuen Long areas of Hong Kong. Baoan is located in south of the Tropic of Cancer and has a subtropical oceanic climate-mild with plenty of sunshine, an average annual temperature of 22 °C, and an annual average precipitation of 1667 mm. The Baoan District has complex terrain, with low hills mainly in the northeast, hills and table I and in the central and northern areas, and mainly alluvial plains and some hilly remnants in the west, while the southwest coast is mostly muddy shoreline, with rich ocean beach resources.

B. *Economic Development*

Baoan, along with Hong Kong, Shenzhen, Guangzhou, and the Pearl River international port city, is an important part of

China's industrial belt. Baoan is expected to become the largest high-tech industrial area and an advanced manufacturing base of Shenzhen. It will also be an important export base for high-tech industries and a logistics hub, while also functioning as a base for leisure, tourism, and eco-tourism.

III. DATA AND METHODS

A. Database

The data set was provided by International Scientific Data Service Platform, Computer Network Information Center, Chinese Academy of Sciences (http://datamirror.csdb.cn) [15]. To reconstruct the land-use change history during 2000–2010, we collected Landsat ETM images at the end of three years-2000, 2005, and 2010. Using ENVI software, we illustrated the land-use change patches by comparing the ETM images (shown as a combination of bands of 543 RGB) from 2000, 2005, and 2010. In addition, topographic maps, statistics, the land-use maps for 2000/2005/2010, and the standard land classification system were used as supporting information to identify the types of land-use changes for each patch[16].

B. Methods

The basic idea of this research was to retrieve the district boundary of different image phases using Landsat ETM+ data, and then to analyze the land use/cover change (Fig. 1, Fig. 2, and Fig. 3). A detailed description of the data processing is as follows.

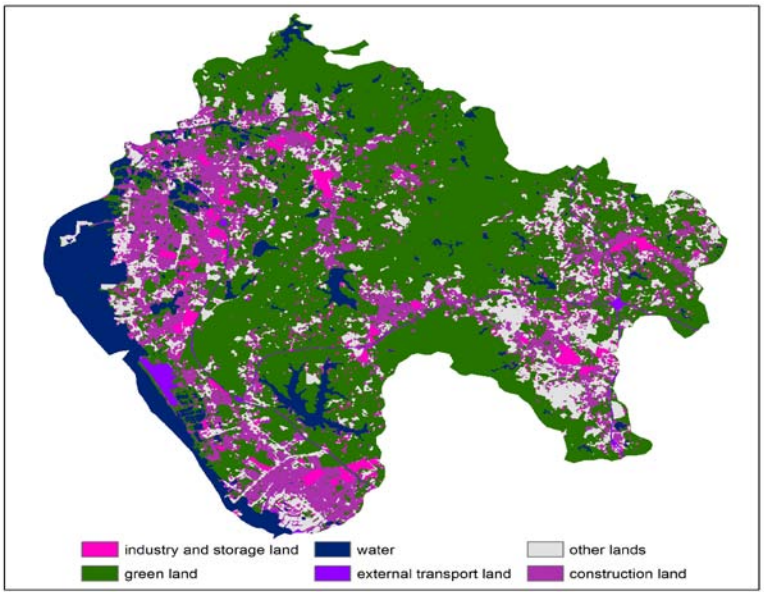

Fig. 1 Class distribution of land use in Baoan in 2000[U1]

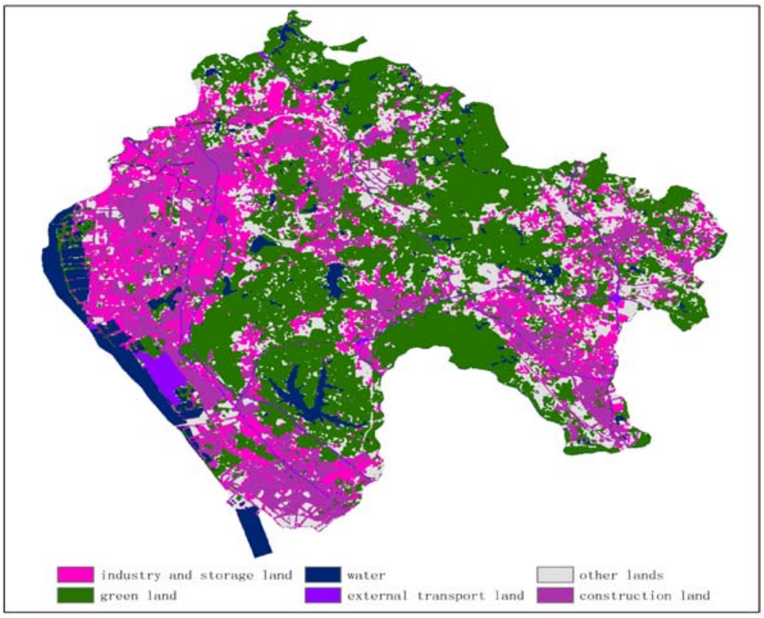

Fig. 2 Class distribution of land use in Baoan in 2005[U2]

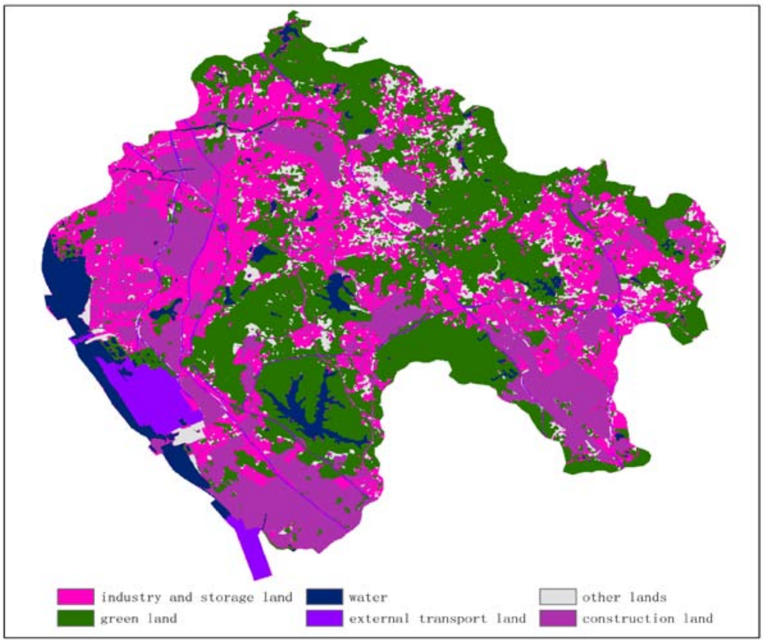

Fig. 3 Class distribution of land use in Baoan in 2010 [U3]

1) Remote Sensing Image Pre-Processing:

In order to retrieve the boundary efficiently, image pre-processing included geometric correction of remote sensing images, study area boundary adjustment, and image enhancement.

Geometric correction and registration: normally, the remote sensing images purchased from the satellite earth station have already been subjected to crude radiometric and geometric correction; therefore, the remote sensing images only need to be subjected to the more precise geometric correction and registration. In this study, image transformation and geometric correction were performed using ERDAS IMAGINE 9.3 software, and control-point correction was used for geometry precise adjustment [17], with reference to the administrative division's photographs of Baoan.

Study area boundary adjustment: the map of Baoan District was digitized using GIS software ARC-GIS 9.3. After setting its coordinates and projection, the Baoan District polygon vector file, including the boundary, was produced. Based on the vector file, the image range of the study area was then extracted using the spatial analyst tool in ArcGIS. In this study area, the borders of the Baoan District expanded through both land reclamation and river deposition. The southwest corner of the port, for example, was reclaimed. Although the coastal waters of the Pearl River tributaries were not part of this reclamation, they were still included in the administrative division map of Baoan District, and in our study. The research area also included the Guangming New District. After image cropping, the image range of the study area was extracted, resulting in Landsat images of the study area as at the end of 2000, 2005, and 2010.

2) Land Use / Land Cover Classification System:

The supervised classification is the most common method in obtaining land use/cover information. In this research, after data pre-processing, a training sample was selected according to the characteristics of the spectrum. Then, the maximum likelihood classification method was applied to the Landsat ETM (Enhanced Thematic Mapper) data by using Envi4.8. This land-use classification was conducted through a combination of computer automation and artificial visual interpretation to guarantee consistency and accuracy of data processing.

Based on the "land use classification" national standards (GB/T21010- 2007) of China [18] and "reference land cover classification specification," the land uses of Baoan District were divided into six types: green land, construction land, industrial and storage land, external transportation land, water and irrigation facilities land, and other land (Fig. 1, Fig. 2, and Fig. 3). Green land includes farmland, woodland, grassland, gardens, and parks. Construction land includes business land, public administration and public services land, residential land, and road construction within the city. Industrial and storage land includes land used for industry and storage. External transportation land includes airports, ports, national highways, state roads, rails, and intercity highways. Water and water-conservancy projects include rivers, lakes, reservoirs, coastal and inland beaches, canals, and land used for hydraulic structures. Other land includes free land, bare land, ridges, and other special lands.

The classifications were identified using the land use and planning maps of the Baoan District, as well as the study area land cover characteristics and remote sensing information penalty. Because some lands that are currently being developed were hard to classify, they were categorized as "other" land.

3) Classification Accuracy Assessment:

Confusion Matrix tools in the ENVI4.8 software were used to test the accuracy of classification results from remote sensing images. From this process, we obtained the total classification accuracy and Kappa index. The classification results that met the accuracy requirements could either be fed into the next stage of processing, or be returned to the previous stage-re-adjustment of the classification template followed by re-analysis. The accuracy of classification results for the three periods of SPOT images was tested and the results are shown in Table I. For the year 2000, the total accuracy was 97.4852% and the Kappa index was 0.9391. For 2005, the total accuracy was 97.4933% and the Kappa index was 0.9652. For 2010, the total accuracy was 97.3072% and the Kappa index was 0.9453. All of the Kappa index values met the requirements of minimum precision of 0.7 [19].

TABLE I EVALUATION ACCURACY OF MAXIMUM LIKELIHOOD

Remote Sensing Image	The Total Accuracy	Kappa Index
Year 2000	97.49%	0.9391
Year 2005	97.49%	0.9652
Year 2010	97.31%	0.9453

IV. RESULTS

A. *Baoan District, 2000–2010 Land Use/Cover Change Analysis*

Based on data derived from remote sensing images, the distribution of the various types of land uses and land cover in Baoan for the years 2000, 2005, and 2010 is shown in Figure 4; exact numerical values and the percentages of change are shown in Tables II, III, and IV. From these tables and figures, the following conclusions can be drawn.

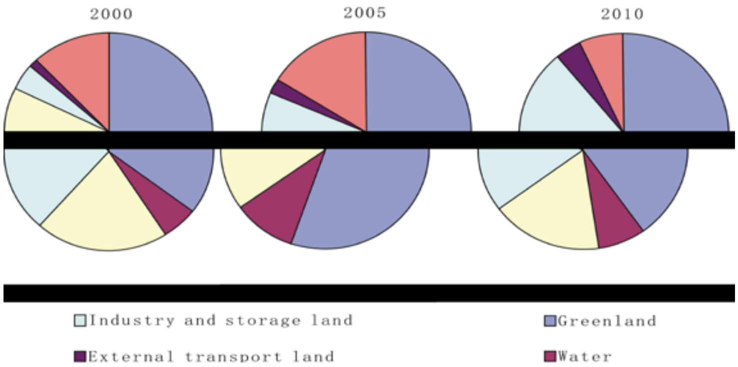

Fig. 4 Class distribution summary of 2000, 2005, and 2010 in Baoan

TABLE II QUANTITATIVE CHANGES IN BAOAN LAND USE FROM 2000 TO 2005

Land Use Types	2000 Area (km^2)	Percentage (%)	2005 Area (km^2)	Percentage (%)	Increased Area (km^2)	Change Rate %
Greenland	388.12	55.14	284.42	39.90	-103.70	-26.72
Water	70.25	9.98	54.58	7.66	-15.68	-22.32
Construction land	120.36	17.10	122.88	17.24	2.52	2.09
Industry and storage land	29.14	4.14	118.47	16.62	89.33	306.56
External transport land	9.36	1.33	14.99	2.10	5.63	60.11
Other land	86.59	12.30	117.58	16.49	31.00	35.80
Total	703.83	100.00	712.92	100.00	9.09	1.29

TABLE III QUANTITATIVE CHANGES IN BAOAN LAND USE FROM 2005 TO 2010

Land Use Types	2005 Area (km2)	Percentage (%)	2010 Area (km^2)	Percentage (%)	Increased Area (km^2)	Change Rate %
Greenland	284.42	39.90	255.98	35.33	-28.44	-10.00
Water	54.58	7.66	39.47	5.45	-15.11	-27.69
Construction land	122.88	17.24	149.52	20.63	26.64	21.68
Industry and storage land	118.47	16.62	199.46	27.53	80.99	68.37
External transport land	14.99	2.10	29.65	4.09	14.66	97.83
Other land	117.58	16.49	50.55	6.98	-67.04	-57.01
Total	712.92	100.00	724.63	100.00	11.71	1.64

TABLE IV QUANTITATIVE CHANGES IN BAOAN LAND USE FROM 2000 TO 2010

Land Use Types	2000 Area （km^2）	Percentage （%）	2010 Area （km^2）	Percentage （%）	Increased Area （km^2）	Change Rate %
Greenland	388.12	55.14	255.98	35.33	-132.14	-34.05
Water	70.25	9.98	39.47	5.45	-30.79	-43.83
Construction land	120.36	17.10	149.52	20.63	29.16	24.23
Industry and storage land	29.14	4.14	199.46	27.53	170.32	584.52
External transport land	9.36	1.33	29.65	4.09	20.29	216.75
Other land	86.59	12.30	50.55	6.98	-36.04	-41.62
Total	703.83	100.00	724.63	100.00	20.80	2.96

1) Changes among the six major land use types varied greatly.

2) Although the amount of green land shrank from 55% in 2000 to 35% in 2010, it was still the predominant type of land in Baoan at the end of 2010. This high percentage reflects the commitment to retaining the natural landscape and green land in Baoan.

3) Industrial and storage land showed the largest increase among the six land classes, increasing gradually from 2000 to 2010 (Fig. 4, Table II). The first increase, from 2000 to 2005, represents a 306.6% increase, and the second increase, from 2005 to 2010, a 68.4% increase. It showed that the speed of industrial development in Baoan slowed down after the initial spurt; 2000–2005 was the golden age of large-scale industrial development in Baoan.

4) While Baoan was dominated by green land and construction land in 2000 and 2005, this predominance changed to green land and industrial and storage land in 2010. Water suffered the largest percentage reduction of any class, with a 22.3% reduction from 2000-2005 and 27.7% reduction from 2005-2010 (Table II, Table III). The second most reduced land was “other” land; its total reduction was 36.0 km2 from 2000 to 2010—a reduction of 41.6%. The major land appropriation for cities and towns of Baoan came from other land, mainly reclaimed beaches. The smallest reduction from 2000 to 2010 was for green land, which was reduced by 132.1 km2—a reduction of 34.0%.

5) Industrial and storage land, external transportation land, saw the largest increases, among the six land classes. From 2000 to 2010, industrial and storage land increased by 584.5% and external transportation land, by 216.7%. From 2000 to 2005, industrial and storage land increased by 89.3 km2 (306.6%); from 2005 to 2010, it increased by 81.0 km2 (68.42%). The increase in external transportation land was comparatively slowing from 2000 to 2005, at 60.1%, but from 2005 to 2010, it grew by 97.8%.

6) From 2000 to 2010, the total land area of Baoan itself had increased by 20.8 km2 (3.0%), primarily from western land reclamation.

B. Analysis of Dynamic Changes of the Structure of Land Uses

1) Transfer Matrix Calculation of Land-Use Areas:

Simply looking at the increases and decreases in the various types of land areas, it is difficult to perceive the changes in the internal structure of land use. To reveal the characteristics of the internal transfer of land use types, land use statistical transition matrices of the area were developed (Tables V–VII) based on the land use maps of 2000, 2005, and 2010 in Baoan and by using the module overlay analysis capability of the spatial analysis feature of ArcGIS software.

TABLE V TRANSFER MATRIX OF LAND USE TYPES IN BAOAN DISTRICT OF SHENZHEN, 2000–2005 (KM^2)

Transfer Matrix		Year 2005						Total
		Construction Land	**External Transport Land**	**Green Land**	**Industry and Storage Land**	**Other Lands**	**Water**	
Year 2000	**Construction Land**	61.35	3.30	10.27	31.91	12.11	1.04	119.99
	External Transport Land	1.03	4.93	1.26	0.88	0.73	0.17	9.01
	Green Land	23.53	4.80	252.77	35.16	71.92	6.61	394.79
	Industry and Storage Land	9.68	0.40	4.15	9.24	4.81	0.10	28.36
	Other Lands	22.34	0.99	11.01	30.99	20.27	0.47	86.07
	Water	7.52	0.49	9.35	10.93	7.33	31.62	67.24
Total		125.44	14.91	288.81	119.12	117.18	40.01	705.46

TABLE VI TRANSFER MATRIX OF LAND USE TYPES IN BAOAN DISTRICT OF SHENZHEN, 2005–2010 (KM^2)

Transfer Matrix		Year 2010						Total
		Construction Land	External Transport Land	Green Land	Industry and Storage Land	Other Lands	Water	
Year 2005	Construction Land	71.97	2.72	4.58	42.29	3.26	0.73	125.54
	External Transport Land	1.47	7.30	1.97	3.66	0.47	0.05	14.92
	Green Land	15.66	2.98	212.78	29.77	23.20	4.38	288.77
	Industry and Storage Land	36.64	2.34	5.21	70.59	3.55	0.93	119.27
	Other Lands	22.72	2.27	25.43	49.30	16.85	0.85	117.41
	Water	0.67	8.71	6.21	4.78	2.17	22.41	44.94
Total		149.10	26.31	256.18	200.39	49.50	29.35	710.84

TABLE VII TRANSFER MATRIX OF LAND USE TYPES IN BAOAN DISTRICT OF SHENZHEN, 2000–2010 (KM^2)

Transfer Matrix		Year 2010						Total
		Construction Land	External Transport Land	Green Land	Industry and Storage Land	Other Lands	Water	
Year 2000	Construction Land	60.15	3.71	6.60	46.00	2.94	0.63	120.02
	Externaltransport Land	0.86	4.97	1.12	1.64	0.35	0.11	9.05
	Green Land	37.66	6.08	228.53	84.17	35.93	2.77	395.14
	Industry and Storage Land	10.49	0.42	3.22	12.88	1.33	0.04	28.37
	Other Lands	31.21	1.16	8.70	39.88	4.93	0.23	86.10
	Water	8.63	6.49	8.52	15.85	4.07	25.66	69.22
Total		149.00	22.83	256.68	200.42	49.55	29.43	707.90

Table V shows the context of land use changes in Baoan from 2000 to 2005. The increase in construction land came mainly from industrial and storage land, and to lesser and decreasing extents from green land, external transportation land, and other lands. The increase in industrial and storage land came mainly from construction land, other land and green land. The decrease in green land came mainly from the expansion of construction land, and industrial and storage land. The decrease in water areas came mainly from the expansion of industrial and storage land, green land, construction land and other land.

Table VI shows the context of land use changes in Baoan from 2005 to 2010.The increase in construction land came mainly from industrial and storage land, green land and other lands. The increase in industrial and storage land came mainly from construction land, green land and other land. The decrease in green land came mainly from the expansion of industrial and storage land, other land, and construction land. The decrease in water areas came mainly from the expansion of external transportation land, green land, industrial and storage land and other land.

Table VII shows the context of land use changes in Baoan from 2000 to 2010. The increase in construction land came mainly from industrial and storage land, green land, external transportation land and other lands. The increase in industrial and storage land came mainly from construction land, green land and other lands. The decrease in green land came mainly from the expansion of industrial and storage land, construction land, other land, external transportation land and water. The decrease in water areas came mainly from the expansion of industrial and storage land, construction land, green land, external transportation land and other lands.

2) Dynamic Degree Analysis of Land Use:

The land-use dynamic degree can describe quantitatively the rate of regional land-use change, greatly facilitating the comparison of regional differences and the prediction of future trends. The dynamic degree of a single type of land use can be expressed as the change in the area of a particular land-use type, in a particular area, within a particular time period, and its formula is expressed as:

$$K = \frac{Ua - Ub}{Ub} \cdot \frac{1}{T} \cdot 100\%$$

where K is the land-use dynamic degree in the study period; Ub and Ua are the areas of the land-use types at the beginning and end of the study period, respectively; and T is the time period for the study. When T is set to one year, K is the annual rate of land–use change in the study area. The land-use dynamic degrees of each type were calculated for each pair of annual periods between 2000 and 2010 (Table VIII).

TABLE VIII DYNAMIC OF SINGLE LAND-USE TYPES IN BAOAN

	2000 Area（km^2）	2005 Area（km^2）	2010 Area（km^2）	2000–2005	2005–2010	2000–2010
Greenland	388.12	284.42	255.98	-5.34	-2.00	-3.40
Water	70.25	54.58	39.47	-4.46	-5.54	-4.38
Construction Land	120.36	122.88	149.52	0.42	4.34	2.42
Industry and Storage Land	29.14	118.47	199.46	61.31	13.67	58.45
External Transport Land	9.36	14.99	29.65	12.02	19.57	21.67
Other Land	86.59	117.58	50.55	7.16	-11.40	-4.16
Total	703.83	712.92	724.63	0.26	0.33	0.30

V. DISCUSSION

Compared to 2000, the land uses in 2010 changed dramatically. Green land was reduced by about 34.05%; water and water facilities, by 43.83% (Table IV, Fig. 5). These changes were due primarily to agricultural structure adjustment and urbanization. Urban development led to the filling in of many small waterways, and the original dense western river network was shifted into other land uses, especially construction land. Industrial and storage land increased significantly, at a magnitude of 6, while external transportation land doubled. Residential areas, business services, and other urban construction land increased by about 24.23%. The major contributors to this increase were rapid economic development and population growth, with the accompanying expansion of housing, roads, and industrial construction. These changes were supported by urban development planning and other government policies. One notable trend was that the area for “other” lands increased during the period of 2000–2005, whereas in the 2005–2010 period, it decreased; this shift reflects the construction boom for factories and residences that began in 2005.

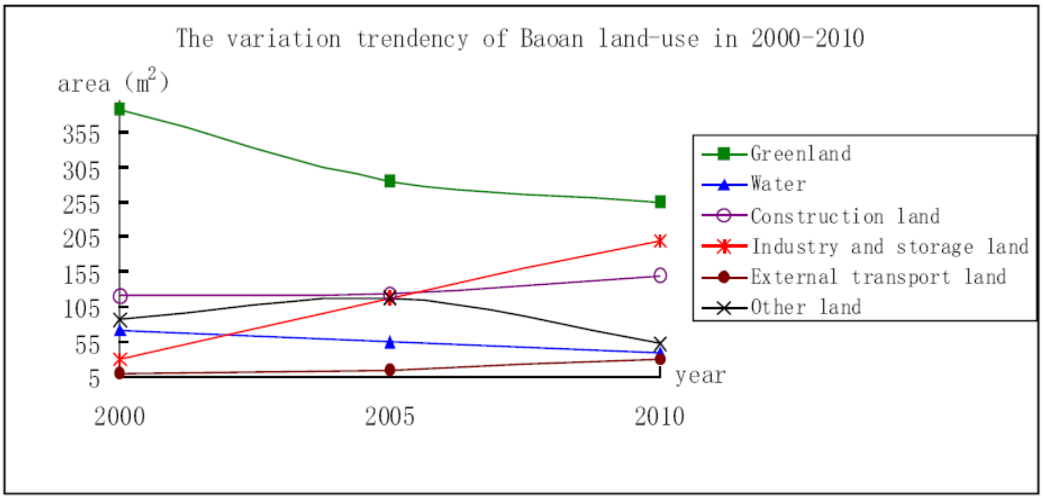

Fig.5 Variation trends in Baoan land use, 2000–2010

VI. CONCLUSIONS

1) The major land use in the study area was green land (at least 35%). Industrial and storage land experienced the largest increase among six land classes. External transportation land experienced the second largest increase, after industrial and storage land. Water experienced the largest reduction among the six classes, followed by “other” land and green land.

2) From 2000 to 2010, the dynamic degree of each single type of land use reflected the speed of changes in land use classes. It can be seen that construction land experienced a slow increase and then a rapid increase; green land reduced rapidly at first and then more slowly; and the area of water increased in the early period and decreased in the later period. The overall trend of the other land from 2000 to 2010 was to decrease.

3) As can be seen from the land use transition matrix in Baoan from 2005–2010, the increase in construction land came mainly from industrial and storage land, green land, external transportation land, and other lands. The increase in industrial and storage land came mainly from construction land, green land, and other lands. The decrease in green land and water areas came mainly from the expansion of industrial and storage land, construction land, external transportation land, and other land.

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REFERENCES

[1] Yu Sihui. Study on Hong Kong land use/cover changes and the driving force "before and after the handover to China," Guangzhou University master paper (in Chinese), 2008.

[2] Turner II, B.L., Skole, D., Sanderson, S., Fischer, G., Fresco, L., Leemans. R. Land-Use and Land-Cover Change Science/Research Plan. IGBP Report No. 35 and HDP Report No. 7. IGBP, Stockholm., 1995.

[3] Lambin, E.F., Baulies, X., Bockstael, N., Fischer, G., Krug, T., Leemans, R., Moran, E.F., Rindfuss, R.R., Sato, Y., Skole, D., Turner, B.L., Vogel, C.. Land-Use and Land-Cover Change (LUCC) — Implementation Strategy. IGBP Report 48 and IHDP Report No.10. IGBP, Stockholm, 1999.

[4] Li, X.B., Wang, X.H.. Change in agricultural land use in China: 1981– 2000. Asian Geographer, 2003, 22(1–2), 27–42.

[5] Weng, Q.H.. Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modeling. Journal of Environmental Management, 64, 273–284, 2002.

[6] X. Wang et al. Land use change and its driving forces on the Tibetan Plateau during 1990–2000. Catena, 2008, 72, 56–66 57,.

[7] Li, X.B.. The change of cultivated land area in China during the past 20 years and its policy implications. Journal of Natural Resources, 1999, 14 (4), 329–333 (in Chinese).

[8] Tan, S.K. Urban land use strategy targeted for dynamic equilibrium of cultivated land areas. Resources Sciences.1999, 21(2), 24–29 (in Chinese).

[9] Bi, Y.Y. The actual changes of cultivated areas since the founding of new China. Resources Sciences. 2000. 22(2), 8–12 (in Chinese).

[10] Li, Y.. China Land Resources. China Land Publishing House, Beijing, 2000.

[11] Chen, L.D., Messing, I., Zhang, S.R., Fu, B.J., Ledin, S.. Land use evaluation and scenario analysis towards sustainable planning on the Loess Plateau in China — case study in a small catchment. Catena, 2003, 54, 303–316.

[12] Lu, L., Li, X., Cheng, G.D.. Landscape evolution in the middle Heihe River Basin of northwest China during the last decade. Journal of Arid Environments, 2003, 53(3), 395–408.

[13] Jia, B.Q., Zhang, Z.Q., Ci, L.J., Ren, Y.P., Pan, B.R., Zhang, Z.. Oasis land-use dynamics and its influence on the oasis environment in Xinjiang, China. Journal of Arid Environments, 2004, 56(1), 11–26.

[14] Zhao, H.L., Zhao, X.Y., Zhou, R.L., Zhang, T.H., Drake, S.. Desertification processes due to heavy grazing in sandy rangeland, Inner Mongolia. Journal of Arid Environments, 2005, 62(2), 309–319.

[15] (2012) The Data Application Environment, Chinese Academy of Sciences, website. [Online]. Available:http://datamirror.csdb.cn.

[16] Liu J, Liu M, Tian H, D Zhuang, Z Zhang, W Zhang, X Tang, X Deng. Spatial and temporal patterns of China's cropland during 1990–2000: An analysis based on Landsat TM data. Remote Sensing of Environment. 2005, 98, 442–456.

[17] Qian Lexiang. Remote sensing digital image processing and geographic feature extraction. Beijing: Science Press, 2004 (in Chinese).

[18] Wu Ye. Another milestone in the land management——"Land use classification" Experts on national standards. Deep in reading, 2007 (in Chinese).

[19] Lucas, I.F.J., J.M..Frans, Van Der Wel. Accuracy assessment of satellite derived land-cover data: a review. Photogrammertric Engineering & Remote Sensing, 1994, 60(4), 410-432.

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(1) Chuanxiu Luo, Zhuo Zheng, Pavel Tarasov, et al, A potential pollen-based climate reconstruction of a modern pollen–climate dataset from arid northern and western China, Review of Palaeobotany and Palynology, 160 (2010), 111-125, SCI

(2) Chuanxiu Luo, Zhuo Zheng, Pavel Tarasov, et al, Characteristics of the modern pollen distribution and their relationship to vegetation in the Xinjiang region, northwestern China, Review of Palaeobotany and Palynology, 153 (2009), 282–295, SCI.

(3) Chuanxiu Luo, Zhuo Zheng, Houxi Zou, et al, A palaeoenvironmental study of the Shiniusi archaeological sites in the Wujiang Drainage Area, upper Yangtze River, Chongqing region, China, Quaternary International, 2011, in press, SCI.

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