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Land Cover Change in Jiaodong Peninsula during the Recent 40 Years Using RS/GIS

Lin Lin*, Shidong Fu, Jian Liu, Qingwei Bu, Yi Tang, Meihua Song and Yanyan Li

Shandong provincial key laboratory of water resources and environment, Water research institute of Shandong province, Jinan, Shandong, 250014, China

*Corresponding author

***Abstract*—Five sets of satellite images of spacing 37 years were used for mapping the land cover change in Jiaodong Peninsula in the present study. Unsupervised classification was applied to classify the land cover into 4 categories including vegetation, built-up land, water body and bared land. Among them vegetation and built-up land were listed as the first and second dominant category accounted for over 90%. Continuous decline in the land covered by vegetation were founded during the study period, whereas the built-up land showed a continuous increase. Symmetrical phenomena of positive and negative change were observed at every study period. It was indicted the conversion of vegetation into built-up land due to rapid population growth and urban sprawl. There was a marked acceleration in the rate of conversion since 1999. It could be seen more clearly from the maps of image interpretation. The change of water body was different from above two classes. The shrinkage and expansion of the category was due to the climate change. Remote sensing and GIS technologies were proved to be effective tools in monitoring land use change in the study.**

Keywords—land cover change; remote sensing; GIS; coastal zone, Jiaodong peninsula

I. INTRODUCTION

Rapid development and population increase of an area require more land and space. Thus, land cover change is unavoidable [1]. Awareness of the land use and land cover is an important process for many planning and management activities [2]. Sustainable development at coastal zone is urgent nowadays worldwide [3]. The land use changes have become an essential parameter in the recent strategies to achieve the integrated coastal zone management that have a great impact on economic development and natural resources managment[4]. Remote sensing and GIS are potentially powerful means of monitoring land-use change at high temporal resolution than traditional methods[5-7]. Jiaodong Peninsula is the largest peninsula in China and located on the east coast of Shandong Province. In view of administrative divisions, it is compose of three cities: Qingdao, Yantai and Weihai. The total land area and population of the peninsula are less than 20% of the whole province, but the gross domestic product accounts for over 30%. The current study aims to identify the land cover change in the peninsula during the period of 1977 to 2014.

II. MATERIALS AND METHODS

A. Satellite Data

Five sets of satellite images spanning 37 years were used as presented in Table 1. One from the landsat MSS obtained in 1977; three from the landsat TM obtained in 1989, 1999 and 2004; one from the landsat ETM obtained in 2014.

TABLE I. THE LANDSAT IMAGES USED IN THIS STUDY

Time phase	Sensor	Spatial resolution (m)
June 1977	MSS	78
May 1989	TM	30
June 1999	TM	30
June 2009	TM	30
May 2014	ETM	15

B. Image Processing

ERDAS IMAGINE and ArcGIS software were used for image processing in this study. An unsupervised classification was performed using the maximum likelihood estimation (MLE) method. The land cover of Jiaodong Peninsula was classified into 4 categories namely; vegetation, built-up land, water body and bared land (Table 2). The thematic maps were produced after merging of small patches and statistical analysis. The area of each category was measured by ArcGIS.

TABLE II. DESCRIPTION OF LAND COVER CLASSIFICATION AT JIAODONG PENINSULA

Class Name	Description
Vegetation	Area covered with woody vegetation, forest, grass and agriculture land which are used for crop cultivation and production of food, vegetables and other mixed varieties.
Built-up land	Land covered by buildings and other man-made structures. It includes residential, commercial services, industrial area, offices, schools, public facilities, roads and scattered rural settlement.
Water body	Areas that are entirely covered by water, such as lakes, reservoirs, rivers, streams and pond water.
Bared land	Area with very little or no vegetation cover.

III. RESULTS AND DISCUSSION

A. Land Cover Classification

It was a challenge to classify the land cover in a region with such a large area and tortuous coastline. The classification results obtained gave an overall accuracy in 1977, 1989, 1999, 2009 and 2014 of 0.75, 0.78, 0.80, 0.85 and 0.82, respectively. The area in different land cover categories at every study period was presented in Table 3 and Figure 1. Table 3 presented the area in different land cover categories at every study period. These data revealed that vegetation occupy the largest share of land cover categories with continuously decline trend during the study periods. Built-up land has showed a continues rising trend during the time periods, however, it was still listed the second dominant land cover. Both upward and downward trends were more clearly shown in Figure 1. Water body in the study area covered 3.14% in 1977 which was close to the share of built-up land at the same time, and then remained at a certain percentage between 3.05% to 4.60%. Bared land only held very small coverage (less than 2.00%) of the total area during the study period.

TABLE III. AREA IN DIFFERENT LAND COVER CLASSES DURING 1977-2014

Land Cover	1977		1989		1999		2009		2014	
	km²	***%***	***km²***	***%***	***km²***	***%***	***km²***	***%***	***km²***	***%***
Vegetation	27911	92.28	26992	89.24	26144	86.43	24138	79.81	20395	67.43
Built-up land	1166	3.86	1710	5.65	2669	8.82	4517	14.93	8454	27.95
Water body	950	3.14	1027	3.40	923	3.05	1391	4.60	1031	3.41
Bared land	220	0.73	518	1.71	511	1.69	200	0.66	367	1.21
Total	30247	100.00	30247	100.00	30247	100.00	30247	100.00	30247	100.00

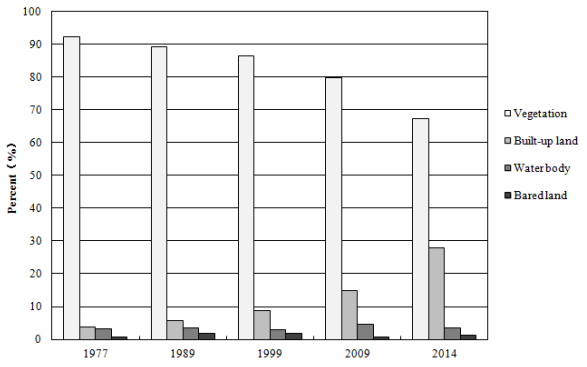


FIGURE I. LAND COVER IN JIAODONG PENINSULA DURING 1977-2014.

B. Land Cover Change

The results of land cover change were given in Table 4 and Figure 2, the rate of change could be observed in Table 5 and Figure 3. Land cover change was discussed in the following paragraphs.

1) Vegetation: The shrinkage of vegetation was declined by 919 km^2 in the first periods from 1977 to 1989 and 848 km^2 in the second periods from 1989 to 1999 at almost the same rate; however, an intensively decrease by 6.63% (201 km^2/year) was appeared in the third periods between 1999 and 2009 which was more than the sum of the decline in the previous 22 years, and further in the fourth periods from 2009 to 2014 decreased by 12.38% with a rate of 749 km^2/year. This indicated 7515 km^2 (24.85%) of vegetation has lost for 37 years between 1977 and 2014 of this study. Above three-quarter of it has lost for the last 15 years, and even half of it for the last 5 years from 2009 to 2014.

TABLE IV. LAND COVER CHANGE AT EVERY STUDY PERIOD

Land cover	1977-1989		1989-1999		1999-2009		2009-2014		1977-2014	
	km²	***%***	***km²***	***%***	***km²***	***%***	***km²***	***%***	***km²***	***%***
Vegetation	-919	-3.04	-848	-2.80	-2005	-6.63	-3743	-12.38	-7515	-24.85
Built-up land	544	1.80	959	3.17	1848	6.11	3937	13.02	7288	24.09
Water body	77	0.26	-104	-0.34	468	1.55	-360	-1.19	81	0.27
Bared land	298	0.98	-7	-0.02	-310	-1.03	166	0.55	147	0.48

TABLE V. RATE OF CHANGE IN LAND COVER AT EVERY STUDY PERIOD

Land cover	Rate of change (km^2/year)				
	1977-1989	***1989-1999***	***1999-2009***	***2009-2014***	***1977-2014***
Vegetation	-77	-85	-201	-749	-203
Built-up land	45	96	185	787	197
Water body	6	-10	47	-72	2
Bared land	25	-1	-31	33	4

2) Built-up land: the increase in built-up land accounted for 1.80% (544 km2) from 1977 to 1989, 3.17% from 1989 to 1999, 6.11% from 1999 to 2009, and 13.02% from 2009 to 2014. There was a longstanding persistent accelerated rising trend through time with a total amount of 7288km2. Similar to vegetation, about 80% of the total increase in built-up land has been contributed by other land cover type in the last 15 years, and more than 50% in the last 5 years. In order to better understand the growth mechanism of the built-up area, we blanked other land use categories in the maps of image interpretation results shown in Figure 4. The accelerated phase since 1999 was clearly displayed. In view of that growth distribution pattern, the increase pole was firstly appeared along the coastline.

3) Water body: Water body showed an small increase of 0.26% from 1977 to 1989 and a decrease of 0.34% from 1989 to 1999, but increased 1.55% from 1999 to 2009 and decreased 1.19% from 2009 to 2014. Overall in the study periods for the last 37 years it has only increased 0.27% (81km^2).

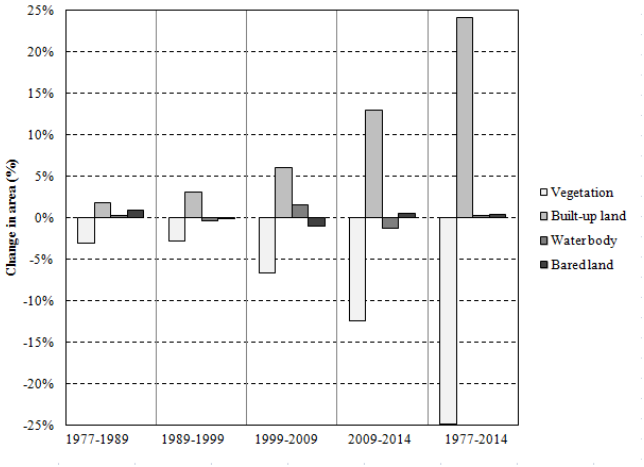


FIGURE II. LAND COVER CHANGE IN JIAODONG PENINSULA DURING 1977-2014.

4) Bared land: The coverage of bared land has experienced an increase of 0.98% at first from 1977 to 1989 and then gradually decline (0.02% and 1.03%) but another rising trend (0.55%) in the last periods from 2009 to 2014, even though the change was too small.

C. Cause of Land Cover Change

The analysis of land cover change indicated that the decrease of vegetation and the increase of built-up land were almost symmetrical at each period (Table 4 and 5, Figs. 2 and 3). It provided a strong possibility of conversion vegetation into built-up land in this study. Due to rapid population growth, there were increased demand of both rural and urban settlement where people live and work. Reference [8] explained alarming rate of population growth resulted for the change of land cover class through time. The mechanism of water body is different from the above two classes. Reference [9] discovered the period change of precipitation series in Shandong province. The negative shifts in the periods 1989-1999 and 2009-2014 were exactly correspond to dry periods of 1975-1995 and 2012-2015, and the positive shifts correspond to flood periods of 1996-2011.

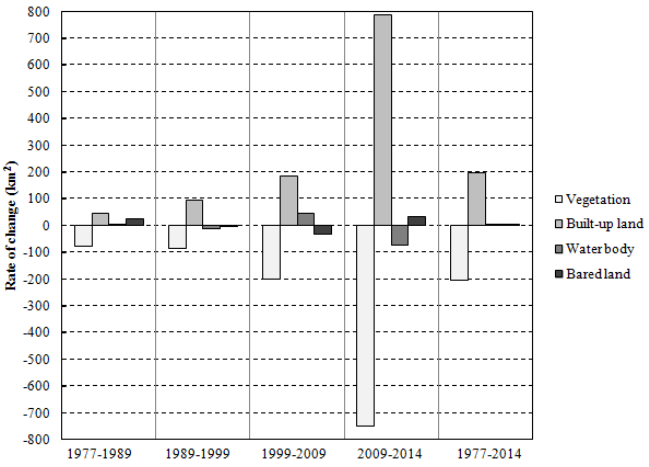
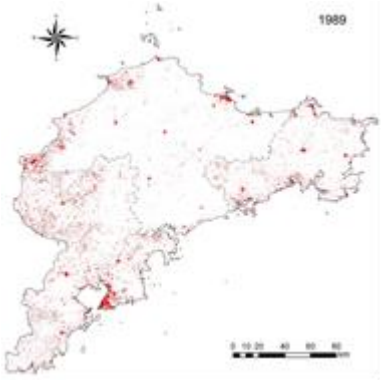


FIGURE III. RATE OF CHANGE IN LAND COVER DURING 1977-2014.



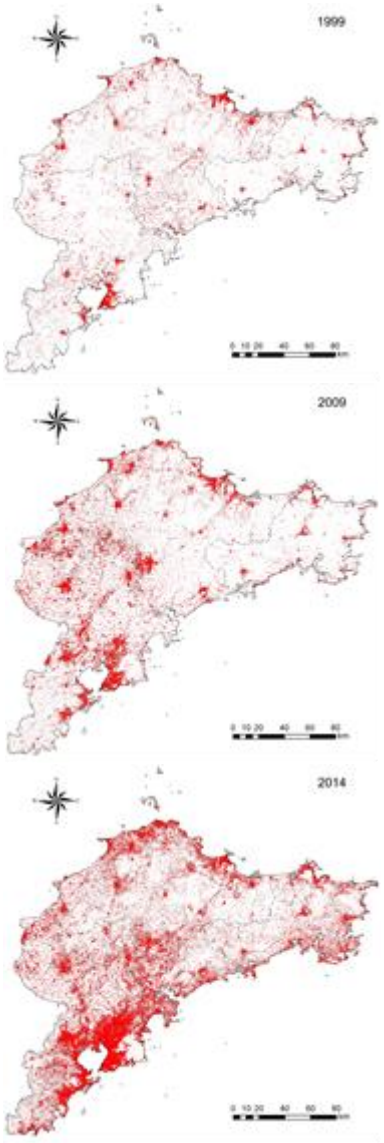


FIGURE IV. THE SPATIAL DISTRIBUTION MAP OF THE INDUSTRIAL AND RESIDENTIAL LAND OF JIAODONG PENINSULA FROM 1977 TO 2014

IV. CONCLUSION

The changes of land cover at Jiaodong Peninsula during the period of 1977-2014 have been investigated using landsat images acquired in 1977, 1989, 1999, 2009 and 2014. The results showed that the main land use of the study area is vegetation, and the second major category is built-up area. The share of these two categories exhibited a huge difference at the beginning of study period in 1977, among which vegetation occupied 92.28% of the total area and the built-up land only accounted for 3.86%. However, at the end of the study period in 2014, the gap was significantly reduced, vegetation and built-up land accounted for 67.43% and 27.95% respectively. This was due to urban sprawl. Through the analysis of the change and the rate of change at every study period, the decline of vegetation and the increase of built-up land were truly symmetrical. Therefore, it is obvious that the decrease of vegetation was due to conversion in built-up land. In terms of the rate of conversion, the abrupt change occurred in 1999, after which there was a marked acceleration. This meant that land use change was influenced by human activity, especially in economically developed area as the consequence of urban sprawl and population growth. Water body and bared land only account for about 5% of the total area. The land covered by water body showed a trend of fluctuation, possible explanation is the fact that the period change of precipitation in the study periods mentioned by other studies. Therefore, the present study is a successful application of using RS and GIS technologies for the quantification of land cover change.

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