Coastline Remote Sensing Monitoring and Change Analysis of Laizhou Bay from 1978 to 2009

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***Abstract*—Coastline of Laizhou Bay was affected by natural and anthropogenic factors and changed severely in the last 31 years. It has great significance to monitor Laizhou Bay coastline change for coastal zone protection and utilization. Based on the extraction of coastline information by selecting 8 remotely sensed images of MSS and TM in the year of 1978, 1989, 2000 and 2009, changes of coastline of Laizhou Bay is analyzed. The results show that: (1) The whole coastline of Laizhou Bay kept lengthening with the speed of 6.04 km/a; (2) The coastline moved 959.2241 km^2 seaward and 0.4934 km^2 landward, that is, 958.7307 km^2 land area increased in total; (3) Transformation of coastline types is mainly from natural types to artificial types. Base on the results, key reasons of the changes of coastline are analyzed, which revealed that, change of the conditions of sediment deposition, construction and extension of saline, cultivated fields and harbors were the main driving factors causing the change of Laizhou Bay coastline.**

***Index Terms*—Laizhou Bay, coastline, remote sensing.**

I. INTRODUCTION

Laizhou Bay coast was influenced by both natural and anthropogenic factors, and changed severely. The natural factors contain changes of Yellow River estuary and tidal surge, and the anthropogenic factors consist of construction and extension of saline, cultivated fields and harbors. It has great significance to monitor Laizhou Bay Coastline change for Laizhou Bay coastal zone protection and utilization. It is also very important to provide scientific and efficient information for decision-making administrations.

Coastline study can be attributed to two main categories, one kind is coastline information extraction research [1-6], the other kind is about coastline change and analysis [7-15].

Some researchers have made studies of different parts of Laizhou Bay coastline. Xue Yunchuan et al. collected the modern Yellow River delta Landsat images from 1976 to 2000 analyzing the coastline length change, migration and the delta's time-space developmental regularity [16]; Cui Buli et al. used 18 multi-temporal remote sensing images to analyze coastline evolution of Yellow River estuary and proposed strategies to prevent coastal erosion [17]; Li Yunzhao et al. took Landat TM/ETM+ images to monitor the coastline and area change of Yellow River delta from 1989 to 2009 [18]; Feng Aiping et al. collected ocean charts, water depth maps and TM images to study erosion of south coast of Laizhou Bay from 1958 to 2004 [19]; Zhuang Zhenye et al. studied sand shore erosion of eastern Laizhou Bay [20]. Overall, the researchers studied only partial regions of Laizhou Bay, but not gave the whole situation of coastal Change of Laizhou Bay.

In this paper, Landsat images in the year of 1978, 1989, 2000 and 2009 were collected to extract coastline information by human-machine interaction method. Based on the results of 4 periods' coastline extraction, this paper analyzed movement of coastline and transformation of coastline types. Base on the results, change factors of the coastline are analyzed.

II. STUDY AREA

Laizhou Bay is located in the northwest of Shandong peninsula which is in the southern Bohai Sea. It is one of the three major Bays in Bohai Sea. The study area started at the modern Yellow River estuary to the Qimu cape (Fig. 1).

In this study, Laizhou Bay was divided into two parts: west coast (from Yellow River estuary to tiger head cliff) and east coast (from the tiger head cliff to Qimu cape). Seen from the coastal geomorphology, the west coast is mostly alluvial - coast Plain, the eastern part is mostly alluvial - flood plains; Seen from the coast types, the west coast is affected by many rivers forming silty and muddy coast, distributed a large number of saline and cultivated fields. The eastern part is mostly sandy coast with beach ridges, tombolo and lagoons, developing Laizhou Harbor, Longkou Harbor and other harbors.

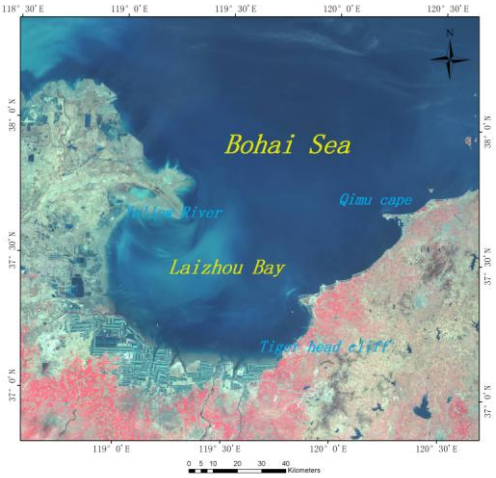

Fig. 1. Study area

III. Data and Method

A. Data

In this paper, the remote sensing data include 2 scenes of Landsat-5 TM images in 1989.3, 2 scenes of Landsat-5 TM images in 2000.9, 2 scenes of Landsat-5 TM images in 2009.7 and 2 scenes of Landsat-3 MSS images in 1978.5 (TABLE I).

TABLE I. Characteristics of remotely sensed data

Sensor	Resolution	Band Combination	Imaging Date
MSS	80m	NIR、R、G	1978.5
TM	30m	NIR、R、G	1989.3
TM	30m	NIR、R、G	2000.9
TM	30m	NIR、R、G	2009.7

B. Method

Field work was executed to get ground control points, that were used to correct images .The RMSE was controlled within 1 pixel. In this paper, there are 4 types of coastline: bedrock coastline, muddy coastline, sandy coastline and artificial coastline. Sun Weifu proposed this 4 types of coastline remote sensing interpretation keys respectively [21] , with field surveying data, by using Landsat images combination of NIR, Red and Green bands, coastline was extracted based on geographic properties (color, texture and vicinity).

IV. Results and Analysis

A. Results

In this paper, 8 Landsat remote sensing images were used to extract Laizhou Bay shoreline types, length and change range.

According to the image information and related data, we analyzed the change process and the factors of change, 4 periods of coastline details are in TABLE II.

TABLE II. Distribution of 4 periods' coastline Unit: km

Types	Year	Coast		Sum
		West	*East*	
Bedrock	1978	——	6.70	6.70
	1989	——	6.05	6.05
	2000	——	5.12	5.12
	2009	——	2.95	2.95
Sandy	1978	——	122.33	122.33
	1989	——	87.00	87.00
	2000	——	57.85	57.85
	2009	——	49.75	49.75
Muddy	1978	166.04	——	166.04
	1989	54.01	——	54.01
	2000	80.75	——	80.75
	2009	86.25	——	86.25
Artificial	1978	110.00	8.98	118.98
	1989	316.55	32.30	348.85
	2000	351.95	67.67	419.62
	2009	349.61	112.81	462.42
Sum	1978	276.04	138.00	414.05
	1989	370.56	125.35	495.91
	2000	432.70	130.63	563.34
	2009	435.87	165.51	601.37

B. Analysis

1) Change of coastline length

It can be seen from TABLE II, the length of the entire coastline of Laizhou Bay increased. Compared with 1978, there was an increase of 81.86 km in 1989, with the average growth of 7.44 km/a; Compared with 1989, there was an increase of 67.43 km in 2000, with the average growth of 6.13 km/a; Compared with 2000, there was an increase of 38.03 km in 2000, with the average growth of 4.23 km/a. In the last 31 years, the coastline length increased 187.32 km, the growth was slowing down gradually, with an average growth of 6.04 km/ a, as is shown in Figure 2.

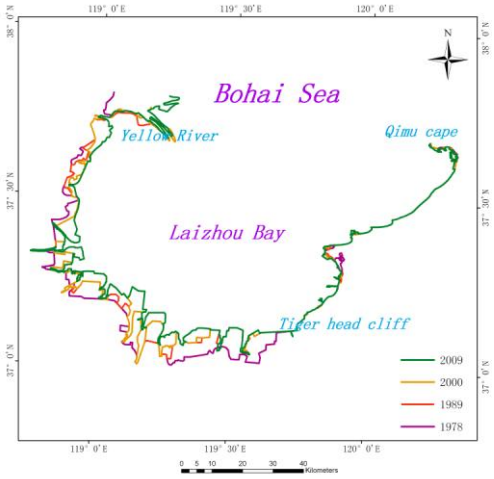

Fig. 2. Laizhou Bay coastline of 1978, 1989, 2000 and 2009,

2) Change of coastline location

Coastline change led to obvious changes in spatial extent of coast accordingly. Compared with 1978, the coastline moved seaward 533.6372 km^2 and eroded back 0.2464 km^2 in 1989; Compared with 1989, the coastline moved seaward 129.8045 km^2 and eroded back 55.3546 km^2 in 2000; Compared with 2000, the coastline grown seaward 359.0467 km^2 and eroded back 8.1566 km^2. In the last 31 years, there were an accretion of land area of 959.2241 km^2 and an erosion of 0.4934 km^2. As is shown in Fig. 3, the significant accretion occurred between 1978 and 2000, and the obvious erosion took place between 1989 and 2000.

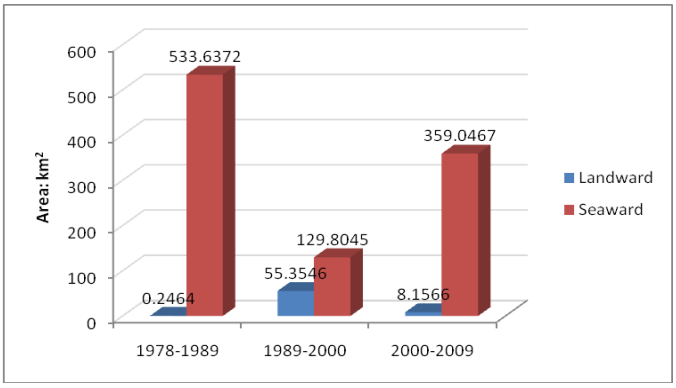

Fig. 3. Coastline change from 1978 to 2009

3) Change of coastline types

In the west Laizhou Bay from 1978 to 1989, because of saline and cultivated fields construction, the Yellow River town, Zhangzhen estuary, coast from Yongfeng estuary to Guangli estuary, coast from Dajiawa Town to Yangzi Town, coast from Bailang estuary to Tushan Town had muddy coastline transforming to artificial coastline; from 1989 to 2000, for the same reason, range from the Yellow River Town to Zhangzhen estuary, Zhangzhen estuary to Yongfeng estuary, Yangkou Town had muddy coastline transforming to artificial coastline; from 2000 to 2009, there was muddy coastline transforming to artificial coastline in the main form of coastal levee and a little saline field.

In the east Laizhou Bay from 1978 to 1989, because of cultivated fields construction, Taiping Bay, Diaolong Tsui, Laizhou Harbor had sandy coastline transforming to artificial coastline. Because of Harbor construction, there were bedrock coastline in Laizhou Harbor and sandy coastline in Longkou Harbor transforming to artificial coastline; from 1989 to 2000, there were sandy coastline from Tiger head cliff to Haimiao Harbor, sandy and bedrock coastline in Diaolong Tsui transforming to artificial coastline in the form of cultivated fields. Because of Harbor construction, there was sandy coastline transforming to artificial coastline in Laizhou Harbor and Longkou Harbor. From 2000 to 2009, there was sandy coastline transforming to artificial coastline in the form of cultivated fields, and sandy coastline and bedrock coastline transforming to artificial coastline because of harbor construction.

V. Change Factors

Based on the results of information extracted and the related information, we analyze the natural and anthropogenic factors of coast change in Laizhou Bay.

A. West Coast

In Yellow River estuary, 1978-1989, Yellow River flowed into the sea from the Qingshui channel, the channel was straight, in the process of epeirogenesis, as the deflection of the Yellow River's flowing gradually to the southeast, the coastline stretched into the bay along the southeast orientation, Yellow River estuary was advancing to the southeast, creasing land very fast, the coastline moved seaward. In June 2, 1996, when Shengli Oilfield changed from sea mining to onshore exploitation, the watercourse was artificially rechanneled in Qing8 Section and northern branch's epeirogenesis began. Thus, it changed the conditions of sediment deposition, making the north branch epeirogenesis rate speed up towards the northeast. It formed a new Sand Tsui in 2000 and coastline moved northward, but original Sand Tsui coast in the south branch has suffered erosion to some extent due to the incoming flow and sediment conditions change. From 2000 to 2009, the new Sand Tsui continued to move seaward and old sand tsui eroded backward since losing sediment supply. Meanwhile, in the last 31 years, the region was also affected by strong winds, waves, storm surges and sea level rising. The sea level rising could do no obvious effect on coastal erosion, but combined with the storm surge, it could make some effects in the south branch, these causes could be ignored in the coast with the high speed epeirogenesis in the north branch.

The region from the Yellow River Town to Tiger head cliff has low and flat plain. In this region, the structure is compact, so that the little permeability made little evaporation, resulting in an ideal salt production area. The construction of saline and cultivated fields driven by economic benefits made land cover extended seaward. In the last 31 years, Guangli saltworks built the new 50 million tons of crude salt project, during these periods, Kenli, Guangrao saltworks had also expanded, in 2006, From Kenli to Dongying, District of saltern and culture areas boundaries have been built into coastal embankments. In 1992, Laizhou saltworks was expanded 100 million tons of crude salt items; During the Eighth Five-Year Plan, Hanting saltworks expanded 100 million tons of crude salt items; Changyi saltworks had also built and expanded; Yangkou saltworks and Daijiawa saltworks were expaned. Yangkou Harbor, Yangzi Harbor, and Xiaying Harbor were expanding construction, supporting convenient conditions of transportation of materials. During the last 31 years, only guangnan reservoir was built up backwards to the land before 1989, Guangrao saltworks scrapped a small piece of culture areas from 2000 to 2009. In general, the coastline of LaiZhou Bay was advancing rapidly to the sea in the last 31 years.

B. East Coast

The east coast of Laizhou Bay is mostly made up of sandy beach, the sheltered conditions are poor, winds and waves are strong, so that harbors can't be constructed in this place. But Longkou Bay coast has Qimu Cape as barrier, Longkou Harbor was developed in the wide and calm bay. Till 1989, there have been 12 berths, followed by continuous expansion, it is expected that, before 2020, Longkou Harbor's throughput will be over 10 times compared to 1989. Laizhou Harbor was built up and expanding in Sanshan island, where the near-shore water depth is deep, tidal range is small. Haimiao Harbor was developed in Taiping Bay where the waves are calm. In addition, Longkou mussel farming has been rapidly developed since 1985 with the mussel farming area gradually built. The anthropogenic factors mentioned above made coastline constantly advancing to the sea.

Waves and tides continually eroded the coast, the Coast continued to retreat; Reduced rainfall and artificial construction of reservoirs resulted in a decrease of river runoff; Sea level rise and storm surge interacted; Beach sand mining developed with the growth of construction and industrial sand use. These factors made Diaolong Tsui coast erode from 1978 to 1989. But since 1978, the development of shrimp cultivated industry fields and scallop aquaculture in Laizhou city has continued to expand. The expansion of the cultivated area of Laizhou City concentrated in Diaolong Tsui and Taiping Bay, causing the coastline constantly advancing to sea.

VI. Conclusion and Discussion

In this paper, we take Laizhou Bay as study area, based on the extraction of length, location and types of coastline with human-machine interaction method by selecting 8 remotely

sensed images of MSS and TM in the year of 1978、1989、2000 and 2009, key reasons of change of coastline in the last 31 years are analyzed. The conclusions are as follows:

(1) In the last 31 years, the coastline length increased 187.32 km, with an average speed of 6.04 km/a;

(2) The coastline moved seaward 959.2241 km^2 with the speed of 30.9427 km^2/a, and moved landward 0.4934 km^2 with the speed of 0.0159 km^2/a, that is, 958.7307 km^2 land area increased in total;

(3) Transformation of coastline types is mainly from natural types to artificial types.

(4) Change of the conditions of sediment deposition, construction and extension of saline, cultivated fields and harbors were the main driving factors causing the change of Laizhou Bay coastline.

Coastline extraction based on remote sensing technology has the advantage of high spatial and temporal coverage, but it is possible that same features may have different spectral properties and different objects could reflect the same spectrum, therefore, it will affect the accuracy of coastline extraction to some extent. In addition, because of the resolution of remote sensing images, the precision of coastline length and location in this paper is limited.

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