Monitoring Delta Changes of Yellow River by Using Remote Sensing Techniques

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Abstract

The siltation processes of modern Yellow River delta is the most rapid in the world, because of Yellow River's highest sediment contents and frequent changes of terminal courses. The Yellow River transported annually about one billion tons of sediments to its delta and coast. In 1855, the Yellow River dikes were broken at Tong Wa Xiang, Kai Feng, Henan Province, the Yellow River abandoned its former river course to the Yellow Sea through north Jiangshu Province and captured the course of the Da Qing river to the Bohai Bay, where it formed a new delta named modern Yellow River delta. From 1855-1976, the Yellow River shifted its terminal course once every 8-10 years into Bohai Bay, and built up a new sub-delta each time. The recent major terminal channel shift of Yellow River occurred in 1976. Since 1976, Yellow River's terminal course was under control by human, and no big shifted occurred. In this paper, the research progresses on monitoring delta changes of Yellow River using remote sensing and geographical information system (GIS) techniques by Institute of Geographical Sciences and Natural Resources Research (IGSNRR) and others will be introduced. The contents includes: monitoring coastline changes of Yellow River delta by using Landsat images during 1976-2000.

Key Words: Yellow River delta, coastline change, Remote Sensing monitoring

1. Introduction

The Yellow river is the mother river of China, and its suspended silt is the most in the world. In 1855, the Yellow River dikes were broken at Tong Wa Xiang, Kai Feng, Henan Province, the Yellow River abandoned its former river course to the Yellow Sea through north Jiangshu Province and captured the course of the Da Qing river to the Bohai Bay, where it formed a new delta named modern Yellow River delta (Fig.1). From 1855-1976, the Yellow River shifted its terminal course once every 8-10 years into Bohai Bay[1-2] (Fig.2), and built up a new sub-delta each time. The recent major terminal channel shift of Yellow River occurred in 1976. Since 1976, Yellow River's terminal course was under control by human, and no big shifted occurred and just once man-made change in June 1996 .

The modern Yellow River delta is composed of 2 subdeltas and 11 delta-lobes[1] (Fig.2). The

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first subdelta with 6 delta-lobes formed from 1855 to 1934 and its apex is at Ninghai village. The second subdelta with 4 Delta-lobes began its formation in1934 and its apex is at Yuwa village, and last delta-lobe formed from 1976. The Yellow river entered the former Huaihe river at Huayuankou of Zhengzhou in Henan province, passed Jiangsu province and emptied into the Yellow Sea from July 1938 to March 1946. The mean life of the previous delta-lobes is about 12 years. The last lobe lasted 26 years due to human activities from 1976.

The Yellow River carries a great deal of sediment from the Loess Plateau into the Bohai Sea. It is known that the mean water discharge was 33 835 ×106 m^3/ a and sediment discharge 852.5 ×106 t/ a into the delta area from the measurement data at the Lijin station from 1950 to 2000.
Its area was 5 682 km^2 from 1855 to 2001[4]. The mean land growing rate is 41.2 km^2/ a , calculated at the real delta life of 138 years. This rate is 19 times larger than that of the Mississippi delta[5] and 10 times that of the Yangtze delta[6].

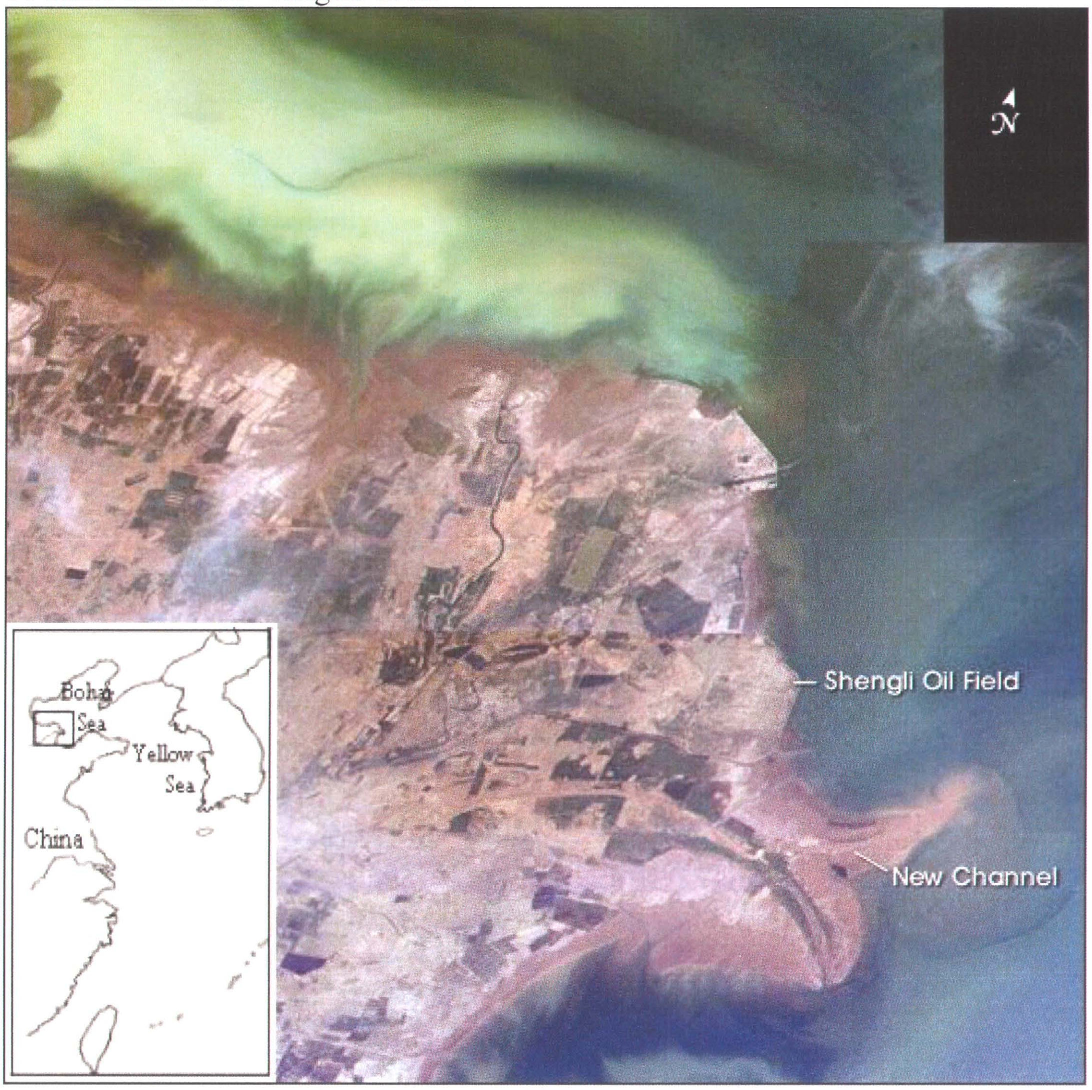

Fig.1 The modern yellow river delta and its location (this image is a Astronaut photograph was taken June 10, 2004 with a Kodak DCS760 digital camera equipped with an 180 mm lens, and are provided by the Earth Observations Laboratory, Johnson Space Center)

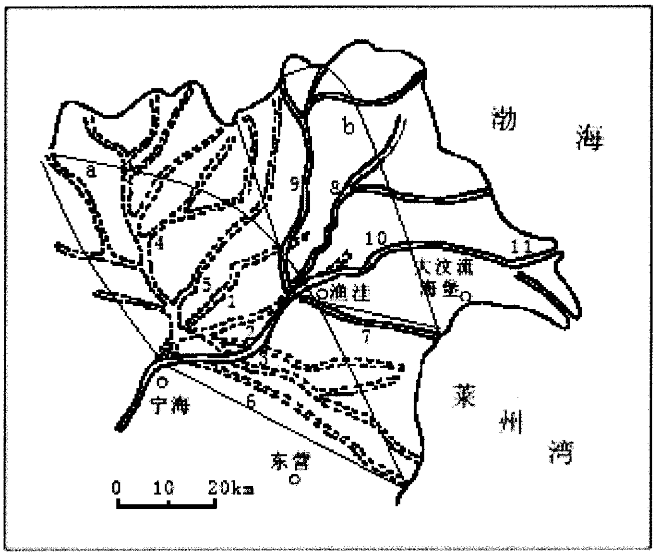

Fig.2 Schematic sketch of tail swinging in different period and developmental stages in the modern Yellow River delta (modified after Yin, 2004) 1:1855.06—1889.03; 2:1889.03-1897.05; 3:1897.05-1904.06; 4:1904.06-1926.06; 5:1926.06-1929.08; 6:1929.08-1934.08; 7:1934.08-1953.07; 8:1953.07-1964.01; 9:1964.01-1976.05; 1976.05-1996.06; 11:1996.06-present
a: first sub-delta; b: second sub-delta

2. Data and method

The multi-temporal Landsat and other satellite images were used as the monitoring data source (tab.1, Fig.3), and the relief maps which scale are 1:50000 were used to registered images.

The threshold method was used to distinguish land and water body because the reflectance of water in near-infrared band is lower than that of land. However the coastlines extracted from remote sensing images are instantaneous boundary between water and land at the time of image acquisition, and boundary location is obviously affected by tide and coast landform. In order to reflect real dynamic changes of coastline of Yellow river delta, various methods for determining coastline from remote sensing images were compared by Survey & Design Institute of the Yellow River Conservancy Commission (YRCC) and it was found that the method of using images in the same month at same tide level is the best. But it is difficult to get multi-temporal remote sensing images which are in the same month at same tide level. In this paper, the mean high water/level method was used to extract coastlines from images. Study results showed the average boundary method for extracting coastline from images can meet the needs of macroscopical analysis[8].

The mean high tide level line located between high tidal flat and mid tidal flat and can be determined by image classification. The different material and exposure time of tidal flat can resulted in different containing water or moisture which spectrum characters are different and can be reflected by shades of gray and color in remote sensing images, so the characters of tidal flat physiognomy and vegetation development are important for image interpretation.

The steps of extracting coastlines from remote sensing images are as follows: firstly using unsupervised classification method to make image pro-classification; secondly selecting training areas, and using supervised classification method to make classification based on the result of unsupervised classification, and extracting coastline from image. Fig.4 showed the remote sensing image (TM7,5,1) and classified image in Diaokou area, and the fig.5 showed remote sensing image (TM7,5,1) and classified image in mouth area in June 25, 1999.

Tab.1 The remote sensing data used to monitor coastline evolution

No	Time	Type	Band	Resolution (m)	No	Time	Type	Band	Resolution (m)
1	1976-12-01	MSS	4	80	11	1992-04-02	TM	7	30
2	1977-05-10	MSS	4	80	12	1993-10-30	TM	7	30
3	1981-11-21	MSS	4	80	13	1994-02-19	TM	7	30
4	1984-10-05	TM	7	30	14	1995-03-19	TM	7	30
5	1985-03-04	TM	7	30	15	1996-05-31	TM	7	30
6	1986-06-05	TM	7	30	16	1996-09-20	TM	7	30
7	1987-05-07	TM	7	30	17	1997-10-09	TM	7	30
8	1988-12-03	TM	7	30	18	1998-05-05	TM	7	30
9	1989-02-13	TM	7	30	19	1999-06-25	TM	7	30
10	1991-01-26	TM	7	30	20	2000-05-02	ETM+	8	15

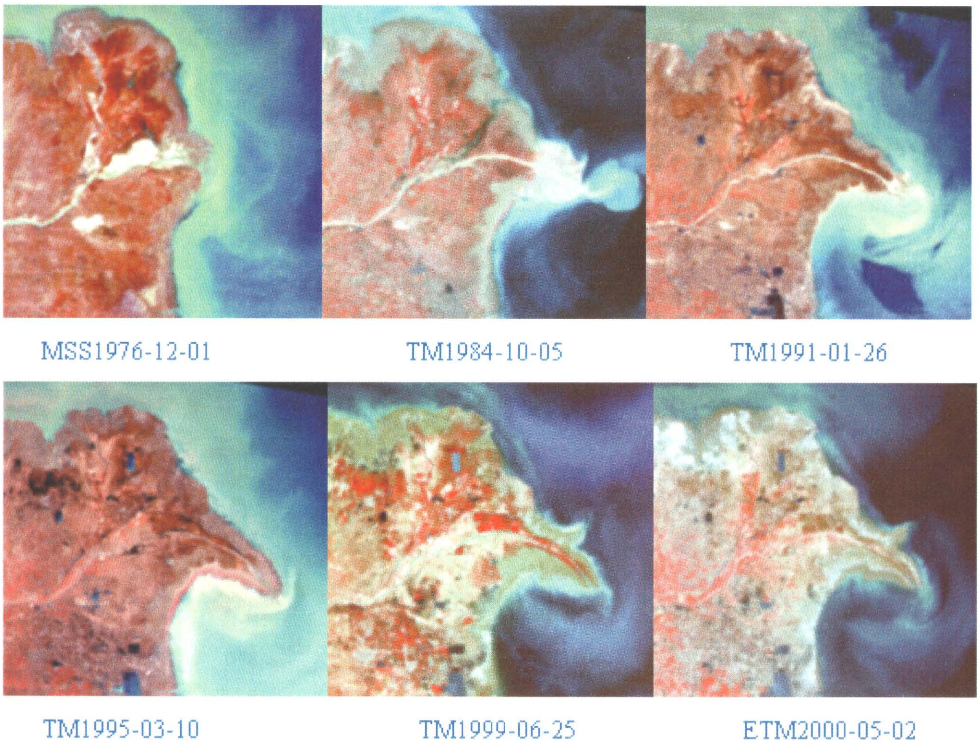

Fig.3 The remote sensing images used to monitor coastline evolution (by IGSNRR)

Fig.4 Remote sensing image (TM7,5,1) and classified image in Tiaohekou area in June 25, 1999 (by ISGNRR)

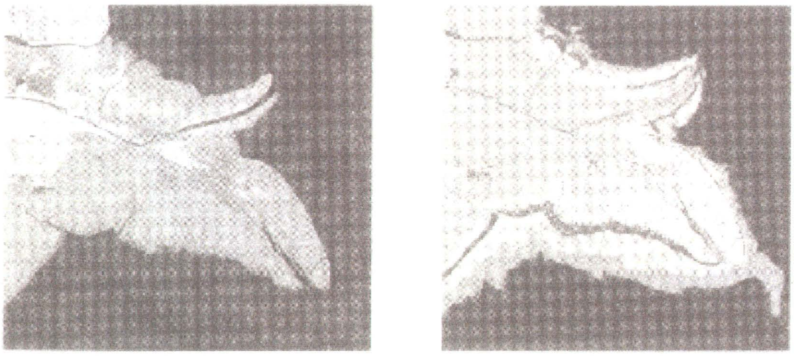

Fig.5 Remote sensing image (TM7,5,1) and classified image in mouth area in June 25, 1999 (by ISGNRR)

3. Results

3.1 Tiaohekou area

The Yellow River course passed western Tiaohekou area during 1909-1926 into Gulf of Bohai. It passed eastern Tiaohekou area during 1964-1976 into Gulf of Bohai and made new land, the max depth of sediments is more than 13m[9] and silting-up coastline is about 17.5km[1].

The western Tiaohekou area has been in week eroding period under the ocean hydrodynamic action for a long time, because Yellow River course changed to other area for 70a. The average eroding speed is 50-80m/a in 1980s, and is 30-50m/a now, and is 50/a from 1976 to present in the western Tiaohekou area[1]. The eastern Tiaohekou area has been in strong eroding period because of no water and sediment reaching the coast since 1976. The coastline eroded back 5-7km and average eroding speed is 200-300m/a in 25a, the eroding speed is 400-600m/a from 1976 to 1989 [1]. Because Yellow River seaport and stone dam protection were built in 1988, the eroding speed slowed down[10] and the eroding speed is 50-150m/a in resent several years[1].

The fig.6 showed that sand mouth eroded back 6km and eroding area is about 100 square kilometer 1976 to 1986, and eroded back 1km and eroding area is about 37 square kilometer 1986-2000 in Tiaohekou area.

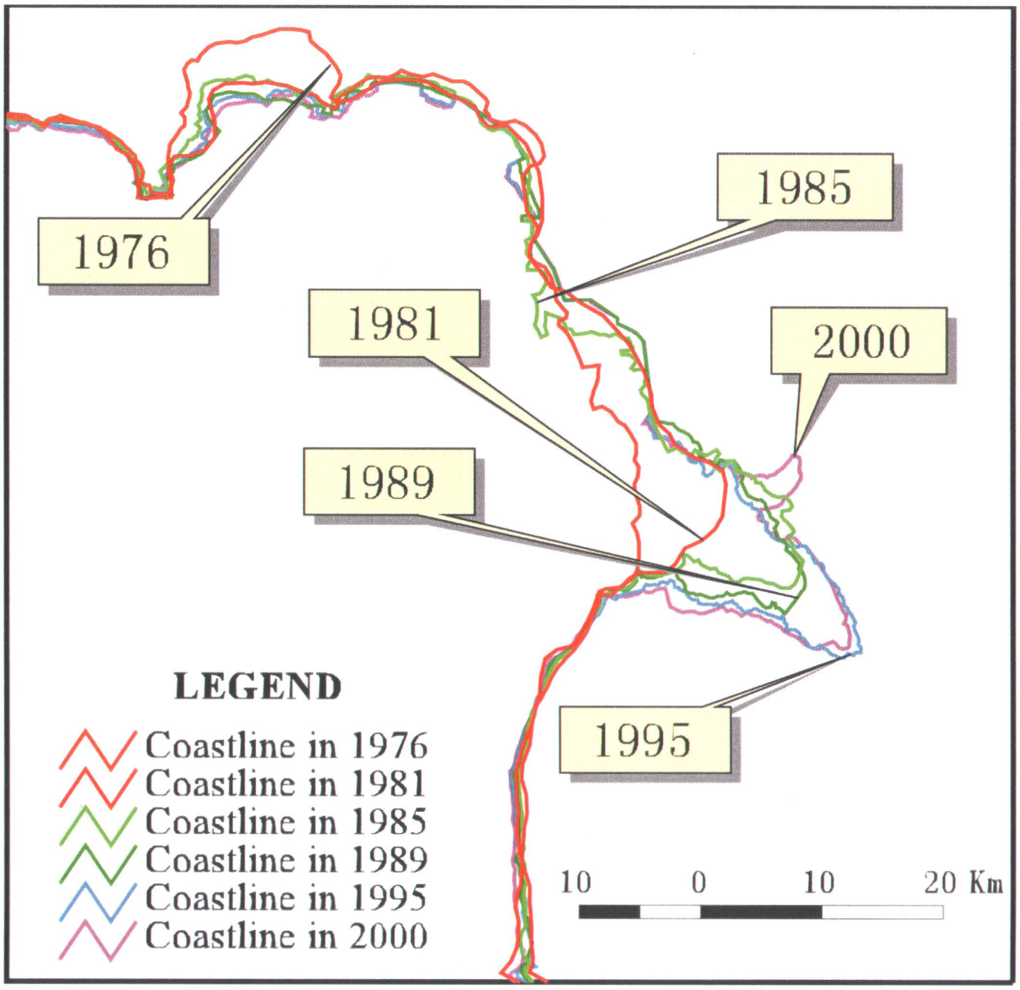

Fig.6 The coastline evolution in the Yellow River Delta from 1976 to 2000 (by IGSNRR)

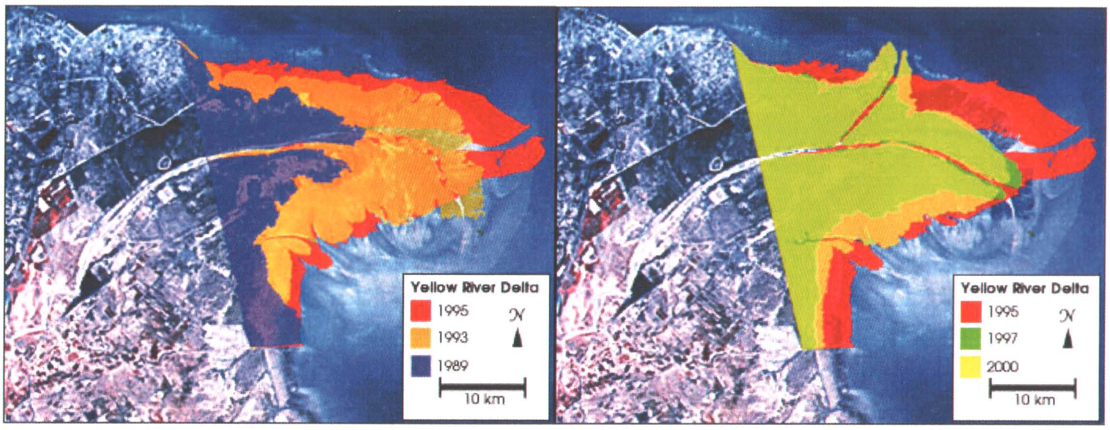

Fig.7 Yellow River delta in mouth area accreted (grew in area) from 1989 to 1995, and eroded (shrank in area) from 1995 to 2000. Each of these outlines of the above-surface delta was measured from an astronaut photograph mapped to the common base (by NASA).

3.2 Mouth area

Since 1976, Yellow River's terminal course passed this area into Gulf of Bohai under control by human, and this area become the fastest changing coast on the Earth's surface.

The silting speed is very fast and average speed is 1-2km/a in estuary area, and coastline silted up 40km and average speed 1.6km/a in the fastest silting-up area from 1976 to 2001[1]. In June 1996 a new channel was cut near the tip of the delta, providing the water and sediment a shorter route to the sea. The coastline of new river mouth has silted up 8km and silting speed is more than 1000m/a since 1996[1].

Between 1989 and 2000, astronauts on the Space Shuttle also documented dramatic changes in the tip of the Yellow River delta (Fig.7). Over this time, several hundred square kilometers have accreted to and been eroded from the coast. The delta grew nearly 400 square km between 1989 and 1995[3], and then began eroding back. Between 1995 and 1997, the delta area eroded back about 250 square km. From 1997 to February 2000, the delta tip again grew nearly 100 square km[3].

Fig.6 showed [7]: from December 1976 to November 1981, sand mouth silted up about 9.4km and new land is about 145km^2; from November 1981 to March 1985, sand mouth silted up about 9.7km and new land is about 68km^2; from March 1985 to May 1987, sand mouth eroded back 5.1km and eroding land is about 45km^2 because of water and sediment reducing; from May 1987 to April 1992, sand mouth silted up about 9.7km and new land is about 119km^2; from April 1992 to May 1996, sand mouth silted up about 5.5km and new land is about 18km^2; In June 1996 a new channel was cut near the tip of the delta and into Gulf of Bohai at Beicha, sand mouth silted up about 5.3km and new land is about 19.2km^2 in new mouth area, and sand mouth eroded back 2.1km in old mouth area from May 1996 to May 2000.

The Yellow River has been engineered for millennia, but recent water demands and water diversions (amplified by several years of drought in the 1990s) have resulted in little or no water reaching the coast. This human factor also drives coastline eroding back in mouth area. From 2002, YRCC has made uniform management for using Yellow River water, which has resulted in having water reaching the coast for several years. In 2005, coastline silted up more than 1.6 km[11].

4. Conclusions and discussions

Remote sensing image analysis is an efficient strategy for examining regional changes that occur over large areas, and provides context for smaller-scale changes. Change can be quantified when the images are referenced to standard maps. Such analyses can identify both natural and human-induced changes, lending some understanding of the processes involved in the coastline evolution.

Reference

[1] Yin Y. H., Zhou Y. Q., Ding D., 2004, Evolution of Modern Yellow River Delta Coast (in Chinese with English abstract) [J]. Marine Science Bulletin, 23(2): 32-40.

[2] Liu G. H., Drost H. J., 1997. Atlas of the Yellow River Delta. The Publishing House of Serveying and Mapping, Beijing. p.24-27.

[3] http://earthobservatory.nasa.gov/Study/AstronautPhotography/astronaut_photography2.html

[4] Li G. X., Yue S. H., Zhao D. B., Sun Y. T., 2004, Rapid deposition and dynamic processes in the modern Yellow River mouth[J]. Marine Geology & Quaternary Geology, 24(3):29-36.

[5] Roberts H. H., 1997. Dynamic changes of the Holocene Mississippi River delta plain: The delta cycle[J] . Journal of Coastal Research , 1997 , 13(3) : 605 - 627.

[6] Hori K, et al., 2001. Sedimentary facies and Holocene progradation rates of the Changjiang (Yangtze) delta , China [J]. Geomorphology , 41(2-3) : 233 - 248.

[7] Chang J., Liu G. H., Liu Q. S., 2004. Dynamic monitoring of coastline in the Yellow River delta by remote sensing[J]. Geo-information science, 6(1):94-98.

[8] Fan Z. M., Guo Y. S., 1992. Atlas of remote sensing dynamic analysis about Yellow River delta coastal zone. Beijing, Ocean Press.

[9] The science & technology council of Shandong province,1991. The report of Shandong costal and beach investigation[R].In: The investigation report of Yellow River mouth area. Chinese science & technology press. Beijing, pp.65-86.

[10]Zeng Q. H., 1997. The evolution laws and renovation of Yellow River mouth area[M]. Zhenzhou: Yellow River irrigation press.

[11] http://www.people.com.cn