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Influence mechanism of the xiaolangdi hydraulic engineering operation on the evolution of the yellow river estuary coastline

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ABSTRACT

The Xiaolangdi Hydraulic Engineering Operation can affect the coastline evolution to some extent by changing the flow and sediment condition in the Yellow River. The results showed one-year lag in the response of the Yellow River estuary coastline to the flow and sediment condition. The flow and sediment in the Yellow River sharply declined (even exhausted) in the 1990s, showing a negatively increased status for the shortage of flow/sediment supply. The erosion rate of spit in the estuary was 0.45 [km/a] in 1995–2003. The land area erosion rate was 14.9 [km2/a] in the late 1990s, and the bending and complexity degree of the coastline remained at a high level. The flow/sediment regulation of the Xiaolangdi Hydraulic Engineering optimized the flow/sediment allocation after 2002. The spit in the estuary considerably extended, resulting in a land-forming rate 1.24 times higher than that under the natural flow/sediment condition. In addition, the coastline tended to be straight and smooth. The Xiaolangdi Hydraulic Engineering should regulate the flow/sediment within 0.02 [t/m3] and the incoming sediment coefficient to about 0.01 [(kg·s)/m6] in the Lijin station, which is about 20 billion [m3] of flow and 300–400 million [tons] of transported sediment, to drive the coastline development in the positive direction.

KEYWORDS

Xiaolangdi hydraulic engineering; Yellow river estuary coastline; Evolution; Influence mechanism; Fractal dimension.

INTRODUCTION

Coastline evolution results from the synthesis of various factors such as the flow and sediment in the Yellow River, wind waves and tide effects, storm surge, sea level rise, land subsidence and human activities. However, a previous study indicated[1-3] that the coastline evolution in the Yellow River Delta is fundamentally determined by the flow and sediment condition in the Yellow River. The flow into the sea can affect the marine hydrography in the estuary coastline, where sediment is the material basis of the Yellow River Delta. The Yellow River sediment concentration in the estuary that is deposited and extended to the sea as well as the ocean dynamics and evolution in the sea and land of the Yellow River Delta is the most vivacious in earth surface[4]. The Yellow River estuary coastline typically suffers seriously from deposition and erosion, and its evolution rate will be the highest worldwide[5]. High frequency coastline evolution overhangs the ecological environment and the project safety of the coastal areas in the Yellow River Delta to some extent[6]. The 10-year operation of the Xiaolangdi Hydraulic Engineering has changed the natural flow and sediment condition by flow/sediment regulation, which affected the coastline evolution. To date, achievements have been made in the coastline evolution study in the Yellow River Delta. However, the study on the influence mechanism of the Xiaolangdi Hydraulic Engineering on the coastline evolution remains limited.

The consensus of scientists and scholars worldwide suggests the monitoring of the dynamic process of coastline evolution by selecting multi-temporal remote sensing images,[7,8] which have been utilized by China in its coastline evolution study since 1970s Huang Haijun[9] demonstrated the feasibility of coastline evolution in the Yellow River Delta. The remote sensing dynamic analysis atlas of coastal areas in the Yellow River Delta[10] analyzes in detail the deposition and erosion state of the coastline near the Yellow River estuary and the Diao Kou estuary from 1976 to 1989. Many domestic scholars study the coastline evolution rules of the Yellow River Delta from 1975 to 1992,[11] 1976 to 1996,[12] 1976 to 2000,[13] 1976 to 2002[14] and 1987 to 2003 in different perspectives. Zhang Shicheng[15,16] analyzed the reasons of coastline evolution in the Yellow River Delta from the angle of sea power and change in power flow, etc. The countermeasures of sand regulation and protection are also proposed.

Coastal zones are important interface of ecological environment liable to the interference by natural and human factors. Coastline change can affect the coastal resources and ecological processes and then affect the sustenance and development of the coastal population[17,18]. Therefore, the study of coastline evolution is an important endeavor. This paper analyzes the coastline evolution rules in the Yellow River estuary and explores the influence mechanism of the Xiaolangdi Hydraulic Engineering in the coastline, along with the 3S technology and hydrological data support from the Li Jin station. Moreover, the paper provides reference for better development of the ecological benefits for the Xiaolangdi Hydraulic Engineering, theoretical basis for eco-geological environment protection and reduction in the Yellow River Delta, and serve as the national eco-economic region plan in the Yellow River Delta.

RESEARCH BACKGROUND

Research Area Survey. The coastline near Wuhaozhuang and the groove of Songchunrong is stable. This observation led many scholars to select the northern Wuhaozhuang (near Dongying port) to the groove of Songchunrong as the Yellow River estuary coastline[17]. The paper selects the coastline between point A (37°56’N, 119°00’E) to point B (37°33’N, 118°59’E) of the Yellow River estuary as the study area (refer with: Figure 1). This portion suffers from natural disasters of drought and flood, wind, hail, ice run of the Yellow River, and storm surge and so on, which intensify the coastline evolution and weaken the ecosystems.

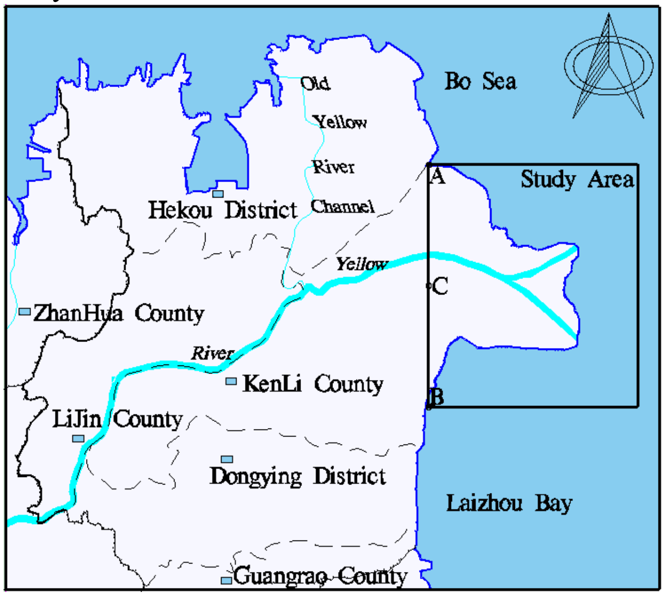

Figure 1 : Location of the study area

The main feature of the Xiaolangdi Hydraulic Engineering is flood control (including ice flood control) and deposition reduction, in consideration of water supply, irrigation, power generation, storing and releasing, and comprehensive utilization. The intervention began in October 1997, whereas the Xiaolangdi Hydraulic Engineering started to impound sediments in October 1999, allowing the ease of regulating the allocation of water resources. The Xiaolangdi reservoir was completed and used in 2001, which put up the necessary condition for the implementation of flow/sediment regulation. Three tests on flow/sediment regulation were performed from 2002 to 2004, and nine production runs were conducted from 2005 to 2010. The implementation of Xiaolangdi Hydraulic Engineering optimizes the flow/sediment allocation and contains the flow break effectively, which changes the flow and sediment condition in the Yellow River under human activity.

Data Processing and Method. The Landsat MSS image of 1977 to 1984 and TM and ETM image of 1989-2010 from 9 to 11 months were selected as data source. (Approximately 1:50 000 topographic map and related materials of Dongying City, supplemented by ERDAS9.2 and ENVI4.7, underwent geometric precision correction processing, image registration, cutting, and classified treatment using the average high tide line method[19] to extract the coastline in the Yellow River estuary. Arcgis9.3 superposition processes were performed to extract coastline length, spit fluctuation, land-forming area, fractal dimension, and so on. The hydrological data from the Li Jin station and the operation information of the Xiaolangdi Hydraulic Engineering were used as reference in a combination of quantitative analysis and qualitative analysis after a series of statistical analysis to establish the connection of hydrological data and coastline data and predict the coastline evolution trends from 2011 to 2020 by the auto-regressive model. (Note: Spit fluctuation is the difference value of twice the vertical dimension between the eastern end and the line linked by point A and point B. Coastline length refers to the total length of the average high tide line. Land-forming area refers to closed area formed by average high tide line and the line linked by point A and point B.)

ANALYSIS OF THE INFLUENCE MECHANISM OF THE XIAOLANGDI HYDRAULIC ENGINEERING ON THE YELLOW RIVER ESTUARY COASTLINE EVOLUTION

Analysis of coastline deposition and erosion

Coastline deposition and erosion have obvious characteristics of space-time variations, and their dynamic process can be broadly divided into four stages (refer with: Figure 2) as follows.

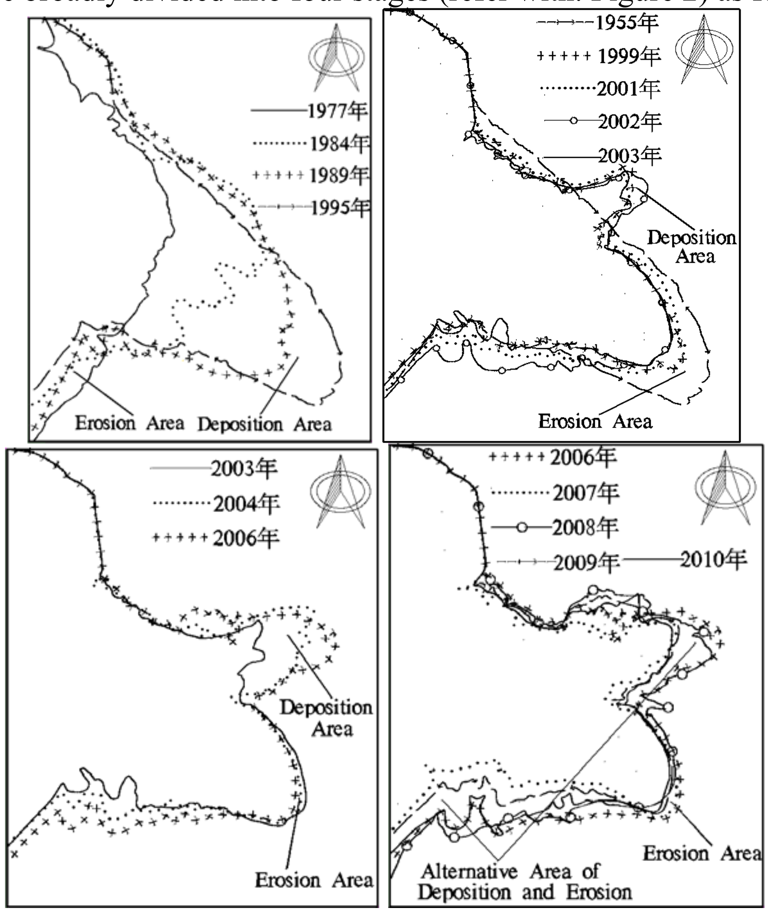

Figure 2 : Evolution process of the coastline in the Yellow River estuary

(I) Tropical expansion stage (from 1977 to 1995). The Yellow River shifted toward the Qingshuigou channel in May 1976. At the bay filling stage from 1977 to 1984, inadequate stream flow, and numerical going-into-sea required the reclamation of the silted sediment of the estuary. The entire coastline quickly silted into the sea on the east drastically with cotton-wool. The construction and reinforcement of an artificial bank near the Gudong oilfield greatly reduced the degree of influence of the natural factors on the coastline. This artificial coastline remained stable since it was built. From 1984 to 1989, the flow path of the Yellow River tended to be stable, with the push of the tide and the Coriolis force. The main channel position stabilized into southeast directions. This position was easy for stream flow to aggregate together toward the sea and transport sediment to places away from the coastline. This process made the spit peak to constantly protrude toward the southeast sea area, and the spit tended to wedge. However, this spit peak has not been completely filled. From 1989 to 1995, the front-end oceanic dynamics of spit got stronger when protruding into a certain degree and a large number of sediment fluxes were carried and spread into the open sea. Moreover, the spit extension and land-making rate was significantly slow, and the Yellow River estuary rapidly protruded toward the sea with a big wedge-like shape. Overall, the coastline mainly extended to the sea, and the spit near the southwest coastline had slight erosion phenomenon.

(II) Rapid erosion stage (from 1995 to 2003). The Yellow River diverted to the Northward route into the sea in July 1996 and was affected by tide and Coriolis force. The Yellow River rapidly silted a small spit extending toward the sea in the northeast direction. The large decrease in flow or even exhaustion resulted in the appearance of the coastline as an alternative evolution of deposition and erosion with slight changes. The spit peak of the northward route continued to extend to the sea toward the northeast. The southern spit continually suffered a strong wash that completely cut off the sediment source. The spit peak drastically moved backward and gradually eroded tending to produce a smooth coastline. Overall, erosion outweighed deposition in the coastline of the Yellow River estuary, and the coastline generally showed a retreating trend, especially very serious atrophy in the southern spit.

(III) Deposition speed accelerating stage (from 2003 to 2006). Given the improved flow and sediment condition, the erosion intensity in the southern spit gradually eased off, but the coastline was still fully retreated with a smaller range. The northward route spit rapidly extended toward the sea with a bigger range. The general trend was that the main deposition body of the spit gradually extended toward the sea.

(IV) Alternative stage of deposition and erosion stage (from 2006 to 2010). Given the large fluctuation of the flow and sediment condition, the northward route spit appeared in an alternative state of deposition and erosion. The southern spit still retreated, but the erosion speed was gradually reduced, which indicated that the coastline segment relatively became straighter and smoother. The coastline on the southwestern swinging with greater range appeared as alternative state of deposition and erosion.

Coastline length analysis

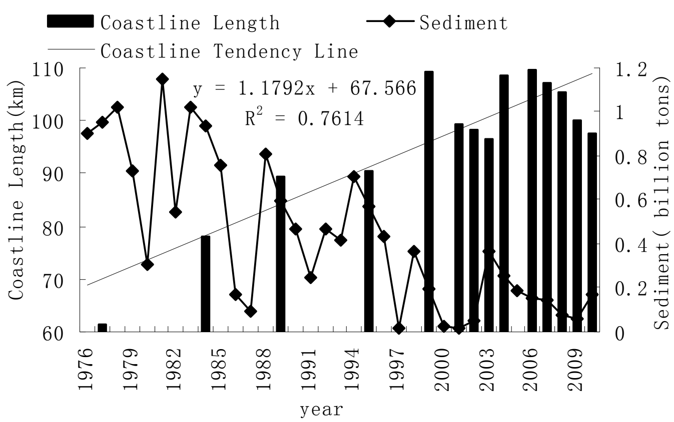

Figure 3 : Annual Variation Curve of Coastline Length and Sediment

Generally, the coastline length in the Yellow River estuary varies with a bigger range from 1977 to 2010. It is increasing year by year with an average growth rate of 1.1 [km/a]. Figure 3 shows the evident lag effect for the response of coastline length to sediment; the lag period is about one year (refer with: Figure3).

The stage variation of coastline length is significant. During the rapid growth phase (from 1977 to 1999), the sediment showed a fluctuating decreasing trend, but still remained at high sediment levels. The coastline was in an alternative state of deposition and erosion, and the entire coastline showed the rule that smaller fluctuation was at short term and larger fluctuation was at long term. The large number of sediment deposit kept the coastline extending toward the sea area, and the coastline length increased at a rate of 2.2 [km/a] in mass. The Xiaolangdi reservoir was used during the sharp reduction phase (from 1977 to 1999), which belonged to the experimental preparatory period of the flow/sediment regulation,. The flow and sediment reached its lowest level in history, which was a typical period of short-term flow and sediment. And the coastline kept eroding and retreating for lack of sufficient flow and sediment, which abruptly reduced the coastline length at a rate of 3.1 [km/a]. The sharp increase phase (from 2003 to 2006) due to the rational allocation of Xiaolangdi caused the flow and sediment to gradually become normal. The gradual change met the deposition condition and quickly extended the coastline to the sea area. The coastline length abruptly increased at a rate of 4.3 [km/a], and this rate was twice of that at the early stage of channel diversion. The slow reduction phase (from 2006 to 2010) showed a fluctuating decreasing tendency of flow and sediment, which reduced the coastline length at a rate of 2.9 [km/a] in spite of the Xiaolangdi regulation effect.

TABLE 1 : Spit Fluctuation

Time Period	Spit Fluctuation (km)	Spit Extension Rate ([km/a])	Ratio of Flow/Sediment ([t/m3])
1977–1984	9.0	1.3	0.0268
1984–1989	2.6	0.5	0.0211
1989–1995	4.7	0.8	0.0279
1995–1999	-2.5	-0.6	0.0282
1999–2003	-1.1	-0.3	0.0138
2003–2006	2.7	0.9	0.0123
2006–2010	-4.4	-1.1	0.0066

Spit fluctuation analysis

The coastline in the Yellow River estuary is a constructive coastline, and the deposition or erosion of the spit is closely related to the flow and sediment condition[20,21]. The spit appears to extend at a rate of 0.34 [km/a] in mass. At the early stage of channel diversion of the Yellow River from 1977 to 1984, the abundant flow and sediment condition, and the reasonable allocation of flow/sediment resulted in the rapid deposition and expansion of the spit at a rate of 1.3 [km/a]. Given the sudden reduction of flow and sediment condition from 1986 to 1987, the flow/sediment sharply decreased to below 0.01 [t/m^3] and the spit peak suffers erosion, which suddenly decreased the extension rate of the spit to 0.5 [km/a]. The river channel was straight under the influence of the Yellow River dam from 1989 to 1995. However, under the influence of flow disturbance, the flow/sediment was generally higher than 0.03 [t/m^3] in mid-1990s, and the spit extended steadily at the rate of 0.8 [km/a]. The length and time of the Yellow River flow disturbance reached the highest level in history from 1995 to 1999. The large number of sediment deposit in the river channel resulted in the lack of sediment source in the Yellow River estuary. Thus, the entire coastline retreated in a distance of 2.5 km. Given the interception of the Xiaolangdi Hydraulic Engineering from 1999 to 2003, the flow and sediment condition reached its lowest level in history. The flow/sediment was below 0.01 [t/m^3], the spit still suffered erosion, and the average erosion rate was up to 0.45 [km/a]. The flow/sediment allocation was more reasonable, the ratio of flow/sediment remained stable near 0.12 [t/m^3], and the spit extended rapidly at a rate of 0.9 [km/a] under the regulation effect of Xiaolangdi from 2003 to 2006. The flow/sediment ratio was below 0.01 [t/m^3], and the spit was eroded at a rate of up to 1.1 [km/a] from 2006 to 2010 (refer with: TABLE 1).

From the foregoing analysis, the spit fluctuation is more sensitive to flow and sediment variation compared with other nature of coastline. Through the Pearson correlation analysis, the spit fluctuation and flow/sediment ratio show a significant quadratic equation with one unknown correlation. The correlation coefficient is 0.447, and the significance is not obvious because of small number of samples. Through regression, the relationship model between the two can be approximated as $V = 8757.7r^2 + 366.66r - 3.0401$, where V represents the spit extension rate and r represents the flow/sediment ratio (refer with: Figure 4). The spit extension rate is subjected to the flow/sediment variation, and the spit will show an extending state when the flow/sediment is between 0.010 [t/m^3] and 0.028 [t/m^3]. Otherwise, it will show a retreating state. The extending length of the spit is proportional to the flow/sediment and vice versa when the ratio of the flow/sediment is less than 0.02 [t/m^3]. To better develop ecological benefit and maintain the coastline dynamic balance, the Xiaolangdi Hydraulic Engineering should properly regulate the flow/sediment within 0.02 [t/m^3], which is about 20 billion[m^3] of flow and 300–400 million[tons] of sediment transportation.

Land-forming area analysis

TABLE 2 : Net Land-forming Area

Time Period	Net Land-forming Area ([km2])	Land-forming Rate ([km2]/a)	Flow (m^3/a)	Sediment (t/a)	Annual Incoming Sediment Coefficient kg.s·m^{-6}
1977–1984	157.8	22.5	318.4	8.3	0.0163
1984–1989	92.3	18.5	256.1	5.6	0.0153
1989–1995	2.5	0.4	185.8	5.0	0.0291
1995–1999	−59.8	−14.9	97.0	3.2	0.0547
1999–2003	−9.9	−2.5	79.6	1.3	0.0291
2003–2006	83.9	28.0	197.5	2.4	0.0110
2006–2010	−55.0	−13.8	173.4	1.2	0.0120

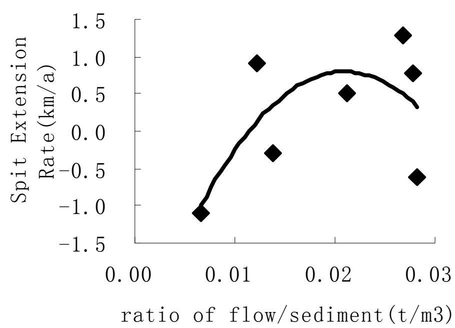

Figure 4 : Relationship Curve between the Spit Extension Rate and Flow/Sediment

An approximate linear relationship exists between deposition or erosion of spit and land-forming area. The extension of spit drives deposition into sea area near the coastline. Moreover, the rapid deposition determines the number of net land-forming area, and rapid erosion determines the number of eroded land area[22]. Generally, the coastline in the Yellow River estuary constantly increases toward the sea at a rate of 6.4 [km^2/a] from 1977 to 2010 and the total of land-forming area is 211.8 [km^2]. The number of net land-forming area in the Yellow River estuary is closely related to the flow and sediment condition. The reduction of flow and sediment toward the sea also slows down the deposition rate of the coastline, and the retreating phenomenon appears even after one year.

TABLE 2 shows the significant positive correlation between the net land-forming area/land-forming rate and the flow and sediment condition. From 1977 to 1995, the flow and sediment are at a higher level, which rapidly forms the land in the Yellow River estuary, and the rate is particularly at maximum at the early stage of channel diversion of the Yellow River. On the other hand, the net land-forming area will decline with the reduction of the flow and sediment, and the land-forming rate is reduced from 22.5 [km^2/a] at the early stage of channel diversion of the Yellow River to 0.4 [km^2/a] in the early 1990s, which points that coastline goes over from the deposition state to the balance state of deposition and erosion. From 1995 to 2003, the flow-disturbing situation in the lower reaches of the Yellow River becomes increasingly severe. The sediment deposit in the channels causes the flow and sediment toward the sea to sharply decline, and the coastline goes over from a balance state of deposition and erosion to erosion and retreating state on all fronts. The coastline erosion in the late 1990s is most serious with a retreating rate of 14.9 [km^2/a]. From 2003 to 2006, the tests on flow/sediment regulation and production runs of Xiaolangdi after 2002 increase the flow and sediment, which meet the deposition condition of the coastline. The coastline protrudes toward the sea at a rate of 28 [km^2/a], and the land-forming rate is 1.24 times higher than that of the natural flow/sediment condition. Consequently, the land-forming advantage under the condition of Xiaolangdi regulation shows an obviously stronger effect than that under the natural condition. From 2006 to 2010, the reduction of flow and sediment caused the coastline to erode and retreat at a rate of 13.8 [km^2/a] in spite of the Xiaolangdi regulation effect that kept the Yellow River from cutoff. The quantitative relationship between the land-forming rate and the flow and sediment can be discussed by a simple mathematical model: $V = 0.177Qw - 1.028Qs - 23.642$, where, V represents the flow and Qs represents the sediment (R2 = 0.527).

According to statistics,[23] the correlation coefficient between land-forming rate per 1 ton of sediment transportation and incoming sediment coefficient is 0.993. This correlation appears to be a significant positive relation at the level of 0.01, and the increase or decrease in the incoming sediment coefficient determines the rapid land-forming rate. The reduction of flow and sediment drastically increases the incoming sediment coefficient from 1977 to 2003, and the land-forming area even shows a negative growth. By controlling a certain amount of flow and sediment from 2003 to 2006, Xiaolangdi causes the incoming sediment coefficient to remain about 0.01 [(kg·s)/m^6], and the land-forming area increases rapidly. Thus, maintaining the deposition state of the coastline is essential to keep the incoming sediment coefficient to be about 0.01 [(kg·s)/m^6].

Coastline fractal analysis.

Based on the ArcGIS9.3 platform, a grid method is adopted to calculate the fractal dimension of the coastline. The method counts the covered number of grid in different scales, using the formula $lg\, N(r) = -D\, lg\, r + A$ to carry out the regression analysis in Excel and gain fractal dimension D, where r, $N(r)$ and A represent the grid length, the covered number of grid and the constant, respectively. Through calculation, the correlation coefficients of fractal dimension regression equation of all time series are all above 0.999. These coefficients indicate that the fractal nature of coastline in the Yellow River estuary objectively exists and has a statistically significant difference.

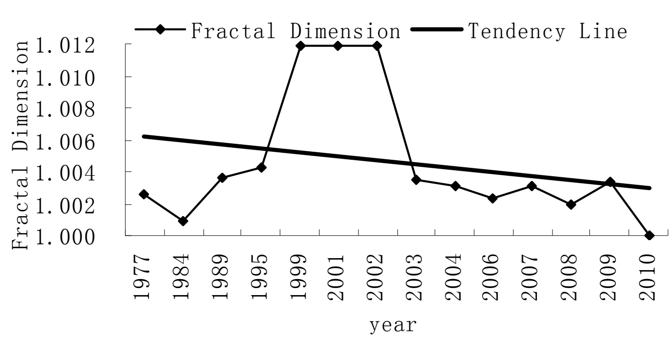

Figure 5 : Annual variation curve of the fractal dimension

Generally, the fractal dimension of the coastline fluctuates from 1 to 1.012. The complexity is small as a whole with a small downward tendency, and the coastline shape tends to simplify. The coastline fractal dimension fluctuates about an average value of 1.0029, and the coastline shape is relatively simple with tendency toward complexity under the condition of abundant flow and sediment from 1977 to 1995. Under the condition of low flow and sediment from 1999 to 2002, most part of the coastline suffers erosion, which increases the bending degree and the fractal dimension to 1.0119 and complicates the coastline. After 2002, the regulation effect of Xiaolangdi causes the coastline to deposit toward the sea area, and the coastline becomes straight. The fractal dimension quickly returns to its normal level with a sudden drop to 0.0084 and remains about 1.0025, and the coastline tends to simplify. The fractal dimension not only reflects the change in complex coastline process but also the dynamic evolution process of the coastline deposition or erosion (refer with: Figure 5).

CONCLUSION AND DISCUSSION

Conclusion

This study objectively reflects the time and space evolution process of the Yellow River estuary through 3S technology and a series of statistical analysis of the coastline evolution data. The dynamic process can be broadly divided into four stages, namely, tropical expansion stage, rapid erosion stage, deposition speed accelerating stage, and alternative stage of deposition and erosion. The influence mechanism of the Xiaolangdi Hydraulic Engineering on the coastline evolution can be summarized as follows.

The coastline variation of the Yellow River estuary is more complex from 1977 to 2010. Overall, the coastline mainly extends to the sea, and its length increases at a rate of 1.1 [km/a]. The spit extends to the sea at a rate of 0.34 [km/a], the net land-forming area is up to 6.4 [km^2] per year, and the coastline shape tends to simplify.

The response lag period of the coastline to the flow and sediment condition of the Yellow River is about one year. Under natural condition, abundant flow and sediment rapidly increase the coastline length and net land-forming area and cause the spit to sharply protrude toward the sea, with a relatively simple coastline shape. The coastline suffers severe erosion because of lacking adequate flow and sediment supply. The bending and complexity degree of the coastline also increase throughout the year of low flow and sediment. The flow/sediment regulation of Xiaolangdi optimizes the flow/sediment allocation after 2002, which causes the coastline to increase toward the sea and the spit to extend largely, with a land-making rate of 1.24 times that of the natural flow/sediment condition. The increasing rate of the coastline length is twice higher than that at the early stage of channel diversion of the Yellow River to Qingshuigou route, and the fractal dimension declines to a normal level. The land-forming advantage under the condition of the Xiaolangdi effect is significant compared with that under the natural condition.

To develop the coastline in a positive direction, the Xiaolangdi Hydraulic Engineering should regulate the flow/sediment within 0.02 [t/m^3] in Lijin station. The incoming sediment coefficient is about 0.01 [$(kg \cdot s)/m^6$] during the operation, which is about 20 billion [m^3] of flow, and the sediment transportation is 300 to 400 million [tons]. In the ideal flow/sediment regulation environment, using the auto-regressive model prediction, the coastline near the northward route spit will further extend to the sea. Moreover, the southern spit will continue its retreating state, and the coastline tends to be more straight and smooth and gradually translates to dynamic balance.

Discussion

The influence mechanism of the Xiaolangdi Hydraulic Engineering on the coastline evolution is briefly discussed and investigated in this paper. The selected remote sensing images are at approximately the same season, which greatly reduce the error of extracting the coastline using an average high tide line method, and meet the requirements of the extracting coastline length, area and fractal dimension, etc.. However, given the lower resolution of the remote sensing images, a higher ground resolution data are required if we complete the high accuracy coastline research. Meanwhile, the paper also has some shortcomings. Given the finiteness of the data collection, remote sensing images over varying intervals of time have a certain restriction to analyze the coastline evolution of contiguous space-time, which is adverse to the improvement of the result reliability. We should master the coastline dynamics and make appropriate precautions to strengthen management and protection for the coastline.

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REFERENCES

[1] Cheng Yiji, Zhang Jianhuai, Yang Xiaoyang; Analysis on Evolution Characteristics of the Coastline of the Yellow River Delta. Yellow River, **33(10)**, 118-120 **(2011)**.

[2] Yuan Xilong, Sun Fanglin, Dong Hong; Study on Regularities and Prediction of Dynamic Variations in the Yellow River Delta Coastline. Coastal Engineering, **26(4)**, 1-10 **(2007)**.

[3] Chang Jun, Liu Gaohuan, Liu Qingsheng; Dynamic Monitoring of Coastline in the Yellow River Delta by Remote Sensing. Geo-information Science, **6(1)**, 94-98 **(2004)**.

[4] B.F.Lam bin, X.Baulies; Land Use and Land Cover Change: Implementation Strategy Stockholm: IGDP Report 48 and IHDP Report10, **(1999)**.

[5] Chang Jun, Liu Gaohuan, Liu Qingsheng; Analysis on Spatial-temporal Feature of Coastline Change in the Yellow River Estuary and Its Relation with Flow and Sand-transportation. Geographical Research, **23(5)**, 339-346 **(2004)**.

[6] Ji Zuwen, Hu Chunhong, Zeng Qinghua et al.; Using Remote Sensing Satellites for Analyzing the Evolution of the Yellow River Estuary Recently. Sedimentation research, **3**, 12-22 **(1994)**.

[7] E.Frihy, S.M.Nasr, M.M.El Hattab et al.; Remote sensing of Beach Erosion Along the Rosetta Promontory, Northwestern Nile Delta, Egypt. INT.J.Remote Sensing, **15(8)**, 1649-1660 **(1994)**.

[8] L.C.Chen, J.Y.Rau; Detection of Shoreline Changes for Tideland Areas Using Multi-temporal Satellite Images. INT. J. Remote Sensing, **19(17)**, 3383-3397 **(1998)**.

[9] Huang Haijun, Li Chengzhi, Guo Jianjun; The appellation of Satellite Images in the Shoreline Change Study of the Yellow River Delta. Marine Geology & Quaternary Geology, **14(2)**, 29-37 **(1994)**.

[10] Fan Zhaomu, Guo Yongsheng; The Remote Sensing Dynamic Analysis Atlas of Coastal Areas in the Yellow River Delta. Bei Jing: China Ocean Press, **(1992)**.

[11] Liu Feng, Chen Shenliang, Peng Jun; Multi-scale Variability of Flow Discharge and Sediment Load of Yellow River to Sea and Its Impacts on the Estuary during the Past 60 Years [J]. Acta Geographica Sinica, **66(3)**, 313-323 **(2011)**.

[12] He Qingcheng, Duan Yonghou; Integrated Management of Coastal Zone in Yellow River Delta——Looking forward to the 21st Century from the Angel of Geosciences. Bei Jing: China Ocean Press, **(1999)**.

[13] Cui Buli, Chang Xueli, Chen Yalin et al. ; Dynamic Monitoring of Coastline in the Yellow River Estuary by Remote Sensing. Science of Surveying and Mapping, **32(3)**, 108-109 **(2007)**.

[14] Zhang Shihua; Coastline Chang and Coast Protection in the Yellow River Delta. Marine Sciences, **27(10)**, 38O41 **(2003)**.

[15] Chen Shenliang, Zhang Guoan, Gu Guochuan; Mechanism of Heavy Coastal Erosion on Yellow River Delta and Its Countermeasure. Journal of Hydraulic Engineering, **7**, 106 **(2004)**.

[16] Cai Zejian, Wu Shuliang; Remote Sensing Analysis of the Coastline Developmengt in Jiangsu Province. Remote Sensing For Land & Resources, **53(3)**, 19-23 **(2002)**.

[17] Tao Minggang; Landsat-TM The Study of Coastline Evolution of the Landsat-TM Remote Sensing Image ——Take Area of Jiulongjiang Estuary as an Example. Hydrogeology & Engineering Geology, **1**, 107-110 **(2006)**.

[18] Yang Hu, Guo Donghua, Wang Changlin; The Application Study of TM-SAR Data Fusion in Dynamic Monitoring of the Yellow River Estuary Spit. Geography and Geo-Information Science, **17(4)**, 15-19 **(2001)**.
[19] Chen Xiaoying, Chen Shenliang, Yu Hongjun et al.; Coastal Profile Types and Evolution Regularities of the Yellow River Delta. Advances in Marine Science, **4**, 438-445 **(2005)**.
[20] Zhang Jianwei, Zhao Quansheng, Wang Jianqiang; Study on RS and GIS-Based Shoreline Evolution of the Yellow River Estuary. Yellow River, **32(4)**, 10-14 **(2010)**.
[21] Zhu Xiaohua; Coastline Fractal Dimension Calculation Methods and Their Comparative Study. Advances in Marine Science, **20(2)**, 31-36 **(2002)**.
[22] Su Yuanyuan, Sun Qinbang, Hou Min; Study on Coastal Fractal of Yellow River Delta. Resources & Industries, **10(6)**, 103-107 **(2008)**.
[23] Ye Xiaomin, Ji Yuqiang, Zheng Quanan et al.; Fractal Analysis of the Coastline Changes of the Jiaozhou Bay. Advances in Marine Science, **27(4)**, 495-501 **(2009)**.