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Coastal Erosion Monitoring and Hazard Degree Assessment at Penglai Sandy Coast Based on Remote Sensing

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Abstract. Coastal erosion disaster is one of the main marine geological disasters. Hazard degree of coastal erosion means that coastal erosion range may be occurred in a future period according to the occurrence mechanism of coastal erosion and its damage characteristic. To effectively cope with the coastal erosion disasters prevention and emergency management needs, the spatial distribution of coastal erosion were obtained, and a shoreline positions prediction model were established by using DSAS, GIS platform, and validated the prediction results by using fields' measure shoreline data at Penglai sandy coast. The results show that (1) there were varying degrees of erosion in the monitoring shore between 2006 and 2015. (2) There are a better coincident between the prediction model results and the fields' measurement results. (3) The spatial shoreline positions of the monitoring shore by the prediction model in 11/13/2016 and 11/13/2020 were obtained. The beach width of the monitoring shore is gradually decreasing, which affects the coastal tourism's use of the beach. These results would be provided a technical support for carrying out the coastal erosion disasters comprehensive management and rational planning of industrial layout along the coast.

1. Introduction

Coastal erosion is the process of coastal change that causes shoreline to migrate to land or tidal zone and bottom bed erosion under the action of oceanic power [1]. Coastal erosion is one of the main marine geological disasters in China's coastal areas, posing a comprehensive and lasting threat to the sustainable development of coastal zone resources and environmental protection in coastal areas. According to the 2008 China Marine Disaster Bulletin, the length of coastal erosion in China is 3,708 kilometers, of which the total length of sandy coastal erosion is 2,469 km, accounting for 53% of all sandy shores. Shandong Province sandy coast is one of the severely eroded areas. Coastal erosion causes significant economic loss, ecological damage and societal problems, loss of property, infrastructure and beach width annually causes millions economic damage, loss of valuable coastal habitat and presents significant management issues [2]. How to carry out coastal erosion disasters comprehensive management is the key issue of the current need to be resolved.

At present, the methods and means for coastal erosion monitoring and assessment can be summarized into two types, one is the traditional conventional monitoring and evaluation methods; the other is the remote sensing image data identification monitoring and evaluation methods. The traditional conventional methods of monitoring and evaluating coastal erosion, it is mainly possible to use the historical sea chart, topographic map, on-site field profile monitoring of ground survey and profile monitoring, and ocean dynamic condition research to obtain information on the possible erosion status of the monitoring shore [3-5]. The method of coastal erosion monitoring and assessment based on remote sensing image data identification mainly uses remote sensing image data from



different periods to identify the shoreline erosion data of the monitoring shore segment based on the identification of the acquisition of shoreline data in different periods and the GIS platform [6-8].

Disaster risk assessment is an important component of disaster reduction and emergency response, and it has great significance in reducing disaster losses and carrying out prevention work [9-10]. Hazard degree assessment is an important part of disaster risk assessment, and it is the key to achieving the disaster risk assessment. Hazard degree were defined as the probability of disaster occurrence, and reflects the nature of the disaster from the traditional definition [9-10], but in terms of coastal erosion disasters, hazard degree of coastal erosion is defined as coastal erosion range may be occurred in a future period according to the occurrence mechanism of coastal erosion and its damage characteristic. Research into hazard degree of coastal erosion disasters started relatively recently, with previous studies focusing on the erosion situation analysis [11-13], causes analysis [14-16], forecasts [17-19], and risk assessment [9,20,21], and obtained the corresponding results. In terms of traditional conventional survey methods, there is a big limitation in data acquisition, information processing, multi-temporal observations and other synchronous. Remote sensing is a modern comprehensive detection technology by using physical means, mathematical methods and geology regularity, which have advantages characteristics in wide detection range, collect data quickly, dynamic reflect the changes in the ground-things. Therefore, remote sensing technology is a very effective means in obtaining the continuous and dynamic information of coast from different levels and scales.

The purpose of this paper firstly is to obtain the erosion status of the monitoring shore by using remote sensing technology. Secondly, to establish a model of coastal erosion hazard degree for the study area by using high-resolution remote sensing data based on GIS platform and DSAS analysis extension. Then validate the model by using fields' measure shoreline data. Finally, predict shoreline erosion range in a future period without outside interference conditions according to the model. These results would provide a technical support for carrying out the coastal erosion disasters comprehensive management and rational planning of industrial layout along the coast.

2. Material and Methods

2.1. Data Collection and Workflow

Fig.1 showed that the workflow of Coastal erosion monitoring and hazard degree assessment based on remote sensing. The specific procedure is as follows:

1) **Data collection:** mainly includes at least three different periods of high-resolution remote sensing data and fields' measured data.

2) **Remote sensing data preprocessing:** high-resolution remote sensing data preprocessing were carried out under ENVI or ERDAS Software platform.

3) **Shoreline extraction:** using visual interpretation method to extracted different historic shorelines based on high-resolution remote sensing data and GIS Software platform.

4) **Shoreline changes analysis:** using digital shoreline analysis system (DSAS) software extension to calculate coastal erosion rate under ArcGIS platform, rate-of-change statistics from multiple historic shoreline positions were obtained.

5) **Status assessment of coastal erosion:** according to the spatial distribution of coastal erosion rate and the grade classification of coastal erosion, the results of coastal erosion status assessment were obtained.

6) **Establishment and validation of the prediction assessment model of coastal erosion:** shoreline positions prediction model were established by using DSAS, GIS platform and rate-of-change statistics, and then, validated the prediction results by using fields' measure shoreline data.

7) **Prediction assessment of coastal erosion of monitoring shore:** according to the fields' measure time, prediction of coastal erosion range in future period (11/13/2016 and 11/13/2020) without outside interference conditions were predicted base on the prediction assessment model of coastal erosion.

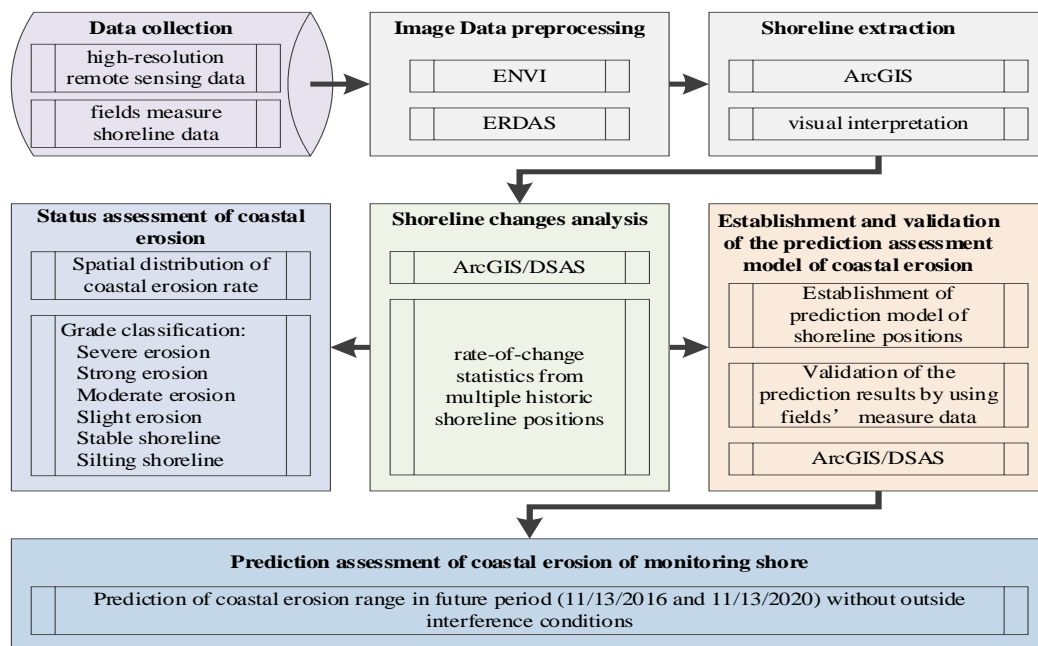


Figure 1. Workflow of Coastal erosion monitoring and hazard degree assessment based on remote sensing

2.2. Data Collection and Shoreline Extraction

Study area is Penglai adjacent sandy coast, which is approximately situated between 37°48'to 37°50' Northern latitude and 120°45'to 120°49'Eastern longitude.

Data include remote sensing data and fields' measure shoreline data. To establish shoreline positions prediction model, remote sensing data with resolution of about 0.5 meter in this study area at 31 May 2006 (QB02) (Fig. 2a), 23 September 2011 (QB02b) (Fig. 2b), 13 July 2015 (PL) (Fig. 2c) were used to analyze the rate-to-change. All of the remote sensing data have been orthorectified, geometric correction, etc. Fields' measure shoreline data were obtained at 10~15 November 2016 by using differential GPS device with accuracy of centimetre-level.

Shoreline information of sandy coast were extracted by visual interpretation method. Sandy coast is generally flat, the upper part of beach is often stacked a beach ridge with sandy and gravelly deposits in parallel to the shore [22]. Beach ridge position is the position of the coastline, and there were usually piled into a trace line at the lower limit of the dry sand beach [23]. On the remote sensing images, spectral reflectance of dry beach is higher, show bright white area on the image, and there are plant debris, clutter and other things accumulated at the trace-line of beach-ridge, and brightness of beach-ridge is lower [23]. Therefore, shoreline information of sandy coast from different period (Fig. 2) were extracted according to the interpretation mark of remote sensing images.



Figure 2. Remote sensing image and shoreline extraction of Penglai monitoring coast in three different periods

2.3. Method

2.3.1. Method of Status Assessment and Prediction Assessment of Coastal Erosion

Using remote sensing image data from different periods to obtain shoreline data from different periods, combined with fields' measure data and other relevant research data, calculate the erosion rate (or siltation rate) of the monitored shore based on the GIS platform and the digital shoreline analysis system (DSAS), and classify the results according to the grade classification standard of coastal erosion intensity.

According to the results of the erosion rate of the monitored shore, the prediction assessment model of coastal erosion is established. The spatial distribution of erosion (or siltation) may occur in a future time in the case of unmanned interference will be estimated by using this prediction assessment model.

DSAS is a software extension to ESRI ArcGIS that enables a user to calculate shoreline rate-of-change statistics from multiple historic shoreline positions [24]. The detail of calculation principles and procedures can be seen in the user guide of DSAS [24].

2.3.2. Grade Classification of Coastal Erosion

According to the characteristics of coastal erosion formation mechanism, combined with a classification standard of coastal erosion intensity by Jiyu Chen [25] developed, the grade classification of coastal erosion intensity are classified using the following table.

Table 1. Grade classification standard of coastal erosion

Erosion intensity level	rate-of-change(S, m/a)
Severe erosion	$S \leq -3$
Strong erosion	$-3 < S \leq -2$
Moderate erosion	$-2 < S \leq -1$
Slight erosion	$-1 < S < 0$
Stable shoreline	$0 \leq S \leq 0.2$
Silting shoreline	$0.2 < S$

3. Results

3.1. Status Assessment of Coastal Erosion of Monitoring Shore

According to the coastal erosion analysis method and process under the ArcGIS9.3 platform and DSAS software extension, the spatial distribution of the shoreline variation rate of the coastal erosion of the Penglai sandy coast in the 2006 ~2015 years was obtained (Fig.3). Fig. 4 is a larger picture of the red box in Fig. 3.

The spatial distribution of the erosion intensity of the monitoring shore between 2006 and 2015 were obtained From Fig. 3.



Figure 3. the spatial distribution of the shoreline variation rate of the coastal erosion of the Penglai sandy coast in the 2006 ~2015 years



Figure 4. A larger picture of the red box in Figure. 3

3.2. Establishment and Validation of the Prediction Assessment Model of Coastal Erosion

According to the materials, methods, and the analysis of DSAS results, shoreline positions prediction model (eq.1) was established.

$$\begin{aligned} x &= x_{\text{int}} + \frac{LRR * \Delta t}{DIS} (x_{\text{int}} - x_{\text{sta}}) \\ y &= y_{\text{int}} + \frac{LRR * \Delta t}{DIS} (y_{\text{int}} - y_{\text{sta}}) \end{aligned} \quad (1)$$

Where, (x, y) is the coordinate of prediction position, units are based on the coordinate system in use; $(x_{\text{int}}, y_{\text{int}})$ is the coordinate of intersection position, units are based on the coordinate system in use; $(x_{\text{sta}}, y_{\text{sta}})$ is the coordinate of baseline position, units are based on the coordinate system in use; LRR is coastal rate-of-change, which obtained from DSAS, its unit is m/yr; Δt is the date, its unit is yr; DIS is the distance between intersection and baseline, its unit is meter. The value of $(x_{\text{int}}, y_{\text{int}})$, $(x_{\text{sta}}, y_{\text{sta}})$, LRR, DIS can be obtained from DSAS analysis results.

According to equation (1), through the calculation and analysis, the prediction of shoreline positions of Penglai monitoring shore in 11/13/2016 were obtained (Fig.5, blue points), and then, fields' measure shoreline data in 11/13/2016 were used to validate the prediction model results (Fig. 5, red points).

As can be seen from Fig. 6, there are a better coincident between the prediction model results and the fields' measurement results, this result can meet the need for coastal erosion disasters prediction work.



Figure 5. Validated the prediction results by using fields' measure shoreline data in 13 November 2016

3.3. Prediction Assessment of Coastal Erosion of Monitoring Shore

According to equation (1) and its validation results, the spatial shoreline positions of the monitoring shore by the prediction model in 11/13/2016 and 11/13/2020 were obtained (fig. 6, blue points is 11/13/2016, yellow points is 11/13/2020).

The blue points mean that the shoreline position of the monitoring shore in 11/13/2016 will be retreated in the blue position without outside interference conditions was predicted according to the prediction model. The yellow points mean that the shoreline position of the monitoring shore in 11/13/2020 will be retreated in the yellow position without outside interference conditions was predicted according to the prediction model, which means that the erosion of the monitoring shore is more severe than 11/13/2016. The beach width of the monitoring shore is gradually decreasing, which affects the coastal tourism's use of the beach.



Figure 6. The shoreline positions of monitoring shore by the prediction model in 11/13/2016 and 11/13/2020

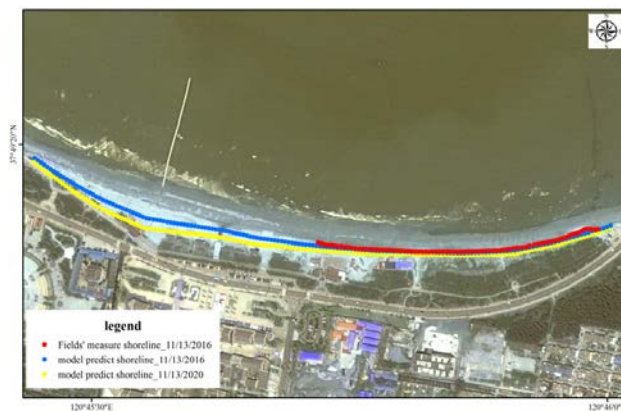


Figure 7. A larger picture of the red box in Fig. 6

4. Discussion

Coastal erosion is the process of coastal change that causes shoreline to migrate to land or tidal zone and bottom bed erosion under the action of oceanic power. Coastal erosion is a slow-changing process of disaster change, and the formation mechanism is more complicated. There are many reasons for the coastal erosion disasters in the study area, but they can be basically classified into two categories: natural factors and human factors. Natural factors mainly include storm surges, wave intrusions, rising sea levels, sediment transport reduced in rivers, and so on. Human factors mainly include coastal sand mining, river water conservancy projects intercepting sediment, coastal engineering to enhance water power, beach vegetation damage, etc. The relationship between these elements and the mechanism of coastal erosion has been obtained correspondingly results [2, 7, 10, 11, 14, 15, 18, 26]. This article will not repeat the relationship between these factors and coastal erosion.

In this paper, the spatial distribution results of coastal erosion status of monitoring shore at Penglai sandy coast from 2006 to 2015 were obtained based on three different periods shorelines extracted by using remote sensing technology and GIS. The information on coastal erosion status obtained based on remote sensing technology is the result of the combination effect of natural factors and human factors, rather than the result of a certain factor. Without considering human intervention (such as shore repair, construction of protective bodies, etc.), the shoreline prediction model is established according to the current operating conditions, and the reliability of the model was validated by fields' measure shoreline data. The range of shoreline erosion of monitoring shore at Penglai sandy coast that is possible to occur in 11/13/2020 is assess by the shoreline prediction model. If the monitoring shore is subjected to human intervention, the prediction results of the erosion range of the monitoring shore will deviate from the actual results.

5. Conclusion

The spatial distribution of erosion status of monitoring shores was obtained based on remote sensing technology method and GIS platform.

Shoreline positions prediction model were established by using DSAS, GIS platform and rate-of-change statistics, and then, validated the prediction results by using fields' measure shoreline data. There are a better coincident between the prediction model results and the fields' measurement results.

the spatial shoreline positions of the monitoring shore by the prediction model in 11/13/2016 and 11/13/2020 were obtained. The beach width of the monitoring shore is gradually decreasing, which affects the coastal tourism's use of the beach.

6. References

- [1] Gibb, J.G.: Rates of coastal erosion and accretion in New Zealand. *New Zealand Journal of Marine & Freshwater Research*, 12, 429--456 (1978)
- [2] Wang, Y.G., Li, S.Y., Miao, L.J.: Coastal erosion disaster of east and west sandy coasts of Liaodong Bay and its prevention and control. *Coastal Engineering*, 24, 9--18 (in Chinese with English Abstract) (2005)
- [3] Addo, K.A., Walkden, M., Mills, J.P.: Detection, measurement and prediction of shoreline recession in Accra, Ghana. *Isprs Journal of Photogrammetry & Remote Sensing*, 63(5), 543--558 (2008)
- [4] Morton, R.A.: Monitoring Beach Changes Using GPS Surveying Techniques. *Journal of Coastal Research*, 19(3), 702--720 (1993)
- [5] Boateng, I.: An application of GIS and coastal geomorphology for large scale assessment of coastal erosion and management: a case study of Ghana. *Journal of Coastal Conservation*, 16(3), 383--397 (2012)
- [6] Marghany, M.M.: TOPSAR wave spectra model and coastal erosion detection. *International Journal of Applied Earth Observation & Geoinformation*, 3(4), 357--365 (2001)
- [7] Kurt, S., Karaburun, A., DemiRci, A.: Coastline changes in Istanbul between 1987 and 2007. *Scientific Research & Essays*, 5(19), 3009--3017 (2010)
- [8] Wen, S.Y., Zhang, F.S., Wang, X., Wang, Z.Z., Li, F., Wang, F., Wang, X.X., Xu, X.G.: Hazard degree assessment of coastal erosion at Tianlongsi adjacent sandy coast. In: 2016 Fourth International Workshop on Earth Observation and Remote Sensing Applications (EORSA 2016), pp. 424--427, IEEE Press, Guangzhou (2016)
- [9] Huang, C.F.: Basic Principles of Risk Analysis of Natural Disasters. *Journal of Natural Disasters*, 8, 21--30 (in Chinese with English Abstract) (1999)
- [10] Xu, L.F., Wen, S.Y., Zhao, D.Z., Xu, X.G.: On the coastal erosion risk assessment indexes. *Journal of Risk Analysis and Crisis Response*, 3, 146--155 (in Chinese with English Abstract) (2013)
- [11] Davidson-Arnott, R.G.D., Ollerhead, J.: Nearshore erosion on a cohesive shoreline. *Marine Geology*, 122, 349--365 (1995)
- [12] Rahman, A.F., Dragoni, D., El-Masri, B.: Response of the Sundarbans coastline to sea level rise and decreased sediment flow: A remote sensing assessment. *Remote Sensing of Environment*, 115, 3121--3128 (2011)
- [13] Liu, Y., Huang, H., Qiu, Z., Fan, J.: Detecting coastline change from satellite images based on beach slope estimation in a tidal flat. *International Journal of Applied Earth Observation and Geoinformation*, 23, 165--176 (2013)
- [14] Zhang, K.Q., Douglas, B., Leatherman, S.: Do storms cause long-term beach erosion along the U.S. East Barrier Coast?. *Journal of Geology*, 110, 493--502 (2002)
- [15] Brunel, C., Sabatier, F.: Potential influence of sea-level rise in controlling shoreline position on the French Mediterranean Coast. *Geomorphology*, 107, 47--57 (2009)
- [16] Huang, G.: Time lag between reduction of sediment supply and coastal erosion. *International Journal of Sediment Research*, 26, 27--35 (2011)
- [17] Hapke, C., Plant, N.: Predicting coastal cliff erosion using a Bayesian probabilistic model. *Marine Geology*, 278, 140--149 (2010)
- [18] Ranasinghe, R., Callaghan, D., Stive, M.J.F.: Estimating coastal recession due to sea level rise: beyond the Bruun rule. *Climatic Change*, 110, 561--574 (2012)
- [19] Walkden, M.J.A., Hall, J.W.: A predictive Mesoscale model of the erosion and profile development of soft rock shores. *Coastal Engineering*, 52, 535--563 (2005)
- [20] Del Río, L., Gracia, F.J.: Erosion risk assessment of active coastal cliffs in temperate environments. *Geomorphology*, 112, 82--95 (2009)
- [21] Corbella, S., Stretch, D.D.: Multivariate return periods of sea storms for coastal erosion risk assessment. *Natural Hazards & Earth System Sciences*, 12, 2699--2708 (2012)

- [22] Office of the 908 Special Expenditure of State Oceanic Administration.: technical regulations of coastline surveying of our Marine Survey and Assessment. Beijing: Oceanic press, Commissioning version (in Chinese) (2004)
- [23] Sun, W.F., Ma, Y., Zhang, J., Liu, S.W., Ren, G.B.: study of Remote Sensing Interpretation Keys and Extraction Technique of Different types of Shoreline. Bulletin of surveying and mapping, 3, 41--44 (in Chinese with English Abstract) (2011)
- [24] Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L., and Ergul, Ayhan.: Digital Shoreline Analysis System (DSAS) version 4.0—An ArcGIS extension for calculating shoreline change (ver. 4.4, July 2017): U.S. Geological Survey Open-File Report 2008-1278 (2017)
- [25] Chen J.Y.: China Coastal Erosion Summary. Ocean Press, Beijing (2010)
- [26] Bao, C.X., Wen, S.Y., Xu, L.F, Wu, T., Zhao, D.Z., Huang, F.R., Xu, X.G.: Suizhong Coastal Erosion Risk Assessment Based on Sea Level Rise. Journal of Catastrophology, 30(1), 205--210 (2015)