MONITORING OF THE CHANGE IN COASTAL ENVIRONMENT IN SOUTHERN PART OF RED-RIVER DELTA FROM SATELLITE IMAGES AND THE MECHANISM OF BEACH EROSION

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ABSTRACT

The purpose of this research is to detect the change of coastal region in southern part of Red-river delta-northern Viet Nam using satellite images. The mechanism of beach erosion in this region has also been verified by using numerical model based on one-line theory. Comparing the satellite images taken from 1975 to 2001 showed that almost beaches in southern part of Red-river delta have been eroded continuously. The result of the simulation based on one-line theory clarified that planting mangrove forest in the river mouth is one of the reason caused severe beach erosion in the southern part of Red-river delta.

KEYWORDS

Mangrove forest, beach erosion, satellite image, one-line theory.

INTRODUCTION

Mangrove forest in the Red-river delta is one of the most important ecosystems in supplying foods and protecting land from beach erosion. The decrease of mangrove forests by defoliant and herbicide during Vietnam war and by constructing shrimp ponds in recent years has weakened coastal defense and caused the beach erosion in many places. This is very important problem to the residents and agricultural areas in this region.

On the other hand, after 1990, mangrove afforestation has been carried out around river mouth which is thought to be one of the cause of rapid beach erosion in this area. The negative effect of mangrove afforestation from the viewpoint of the shore protection has not been evaluated yet.

In order to quantify the change of shoreline and land use, the satellite images taken in different time are used. After that, the mechanism of beach erosion processes are verified by numerical model based on one-line theory.

The study area is the coastal region from Ninh Co river mouth to Ba Lat river mouth which belonged to southern part of Red river delta, northern Vietnam. The location of this area is shown in Fig.1.

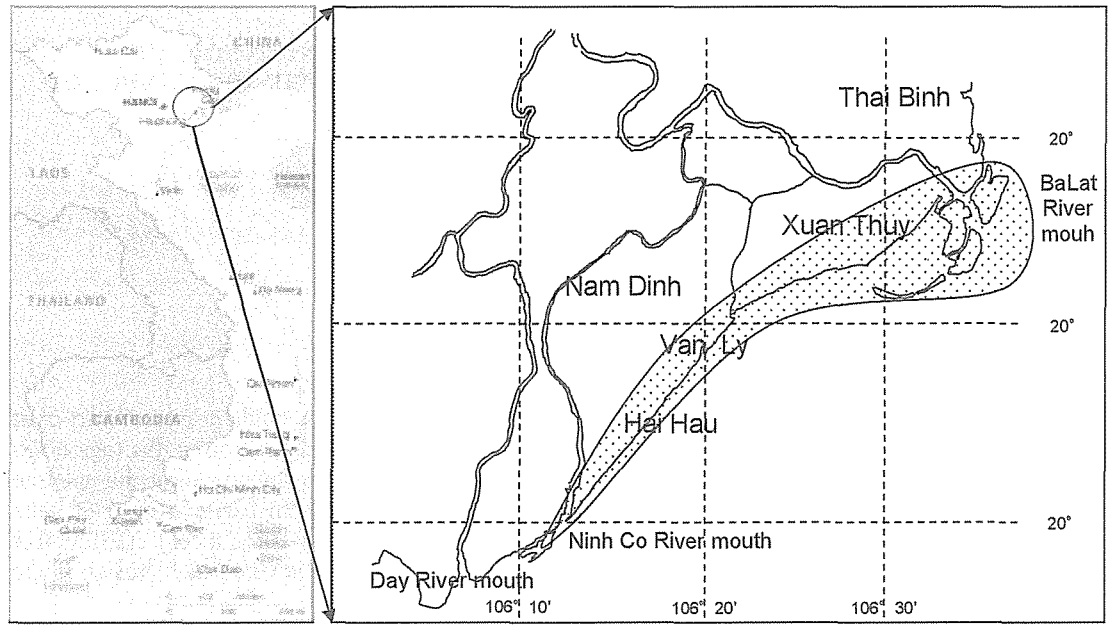

Fig.1. Location of the study area

MATERIALS AND METHODS

Satellite data used and analysis

The satellite images and calculated tidal level used in this study is discribed in Table 1.

Table 1. Satellite data and calculated tidal level used for the study

Satellite	Sensor	Acquisition date	Time (hour:minute:second)	Resolution (m)	Tidal level (cm)
Landsat	MSS	1975 /12/ 29	09:39:39	30	144
Landsat	TM	1989/11/ 23	09:39:00	30	203
Landsat	ETM+	2001/09/ 29	09:39:00	30	221

The author first investigated the change in land use from these images by analyzing the land-cover. A so-called supervised landform classification method was employed.

Then authors determined the location of shoreline by using images of band 5 (1.55 -1.75μm) and band 2 (0.76-0.90μm) of Lansat/TM and evaluated the parameter TM_{5-2} defined as the following equation

$$TM_{5-2} = \frac{Band5 - Band2}{Band5 + Band2}$$

By using the TM_{5-2} images, the radiance values in the pixel between land and sea are changed suddenly so that the shoreline change can be extracted easily (Deguchi, et al., 2005).

Detected change in land-cover and the location of shoreline around river mouth

Figures 2 and 3 show examples of land-cover of Sept. 1998 and Sept. 2001 and change in the shorelines from 1960's to 2001.

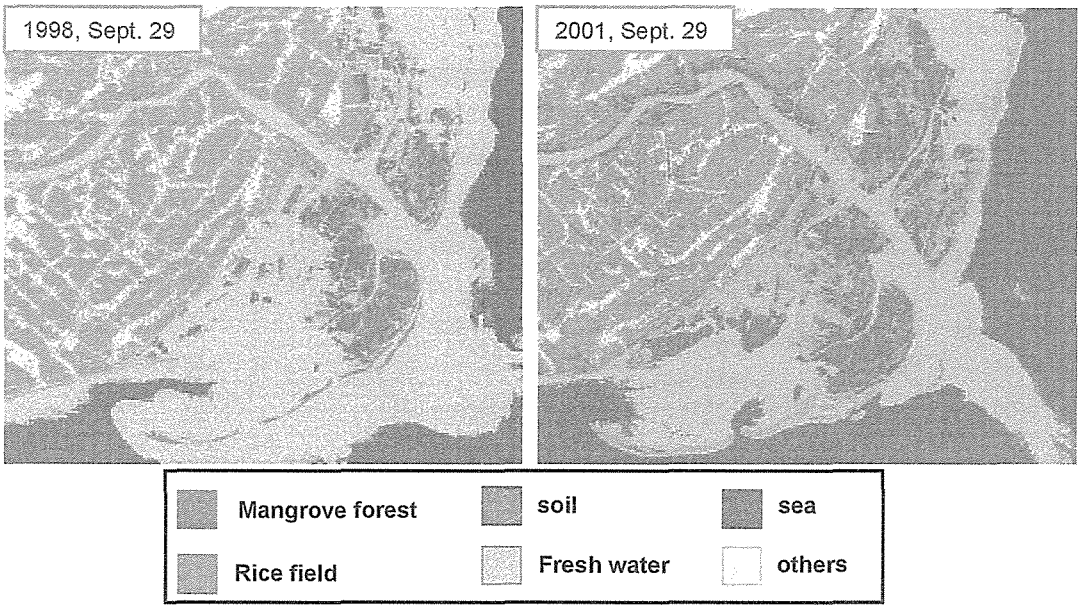

Fig.2 Comparison of land-use in Sept. 1998 and Sept. 2001

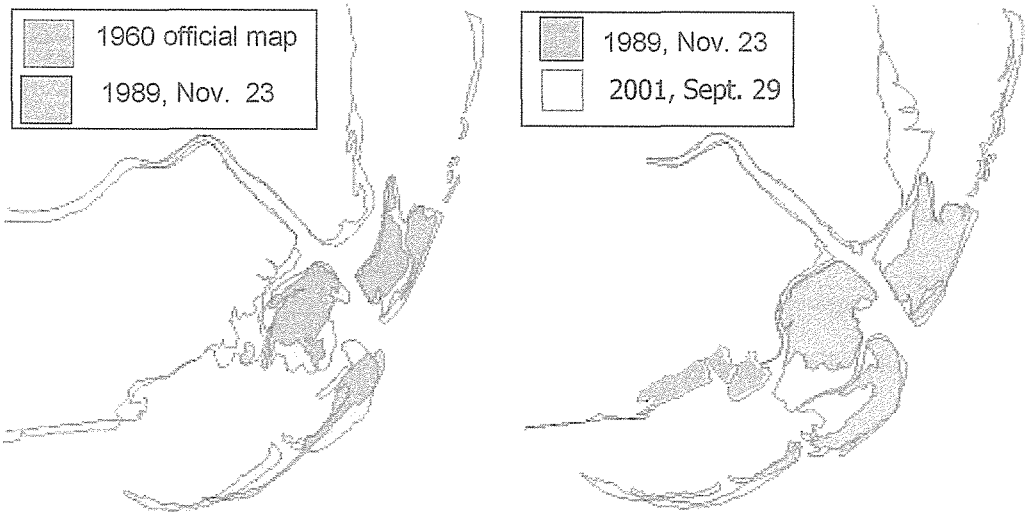

Fig 3 Comparison of the location of shoreline from 1960 and 2001

From Fig.2 it is found that the area of mangrove forest coloring red increased in both sides of the river mouth. On the other hand, the area of land increased significantly on the south part of the river mouth.

Detected change in shoreline from NinhCo river to Xuan Thuy district

Based on the analysis of the satellite images, the result of shoreline extraction will be described in Figs 4,5, 6 and 7 .

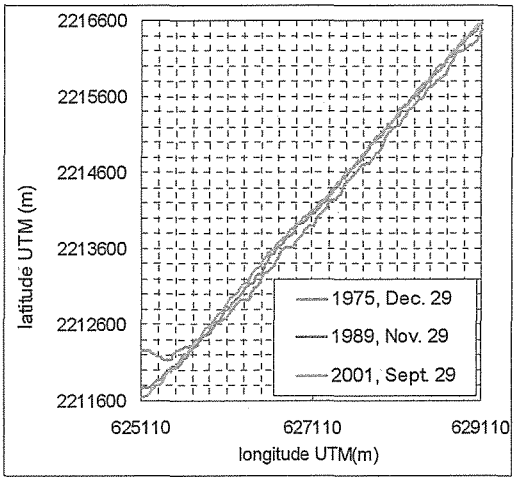

Fig. 4. The shoreline change near NinhCo river

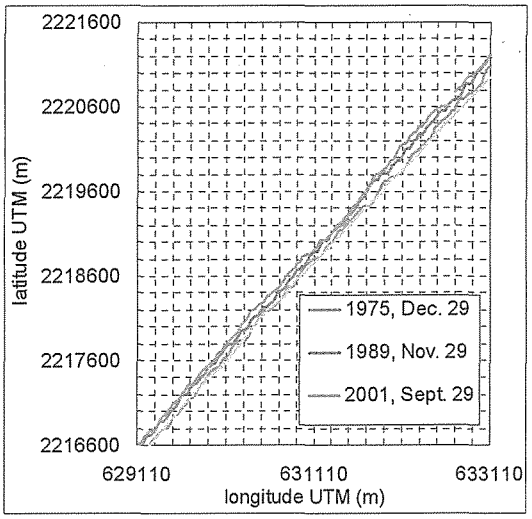

Fig. 5. The shoreline change in Hai Hau district

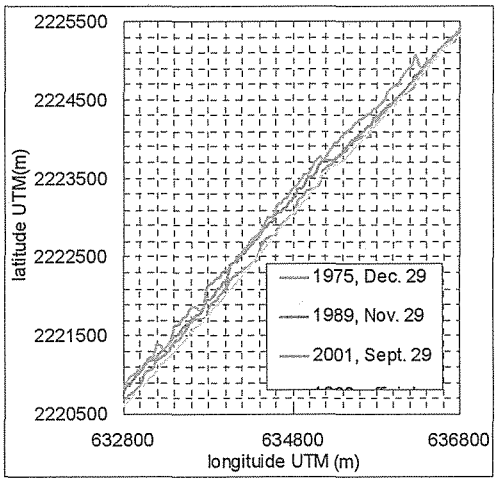

Fig. 6. The shoreline change in Hai Hau district

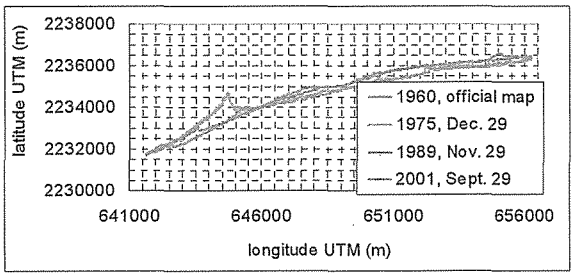

Fig.7. The shoreline change in Xuan Thuy district

Figure 4 shows that the river mouth sand bar grew down toward south and the shoreline in the north part (eastern part further than 62600m) retreated about 150-200m since 1975. This means that the discharged sediment from Ninh Co river did not contribute to the north beach. .This fact is confirmed by the spread of murky water toward south-west in the satellite image.

From Figs 5 and 6 it is found that the retreat of shoreline progressed toward north and the erosion reached at point 636500m longitude in 2001. In this region the shoreline retreated about 200m uniformly. According to the field observation, a so-called double sea-dike system was constructed and the front sea dike was destructed by heavy erosion (Ton That Vinh et al., 1996).

Figure 7 showed that most of the beach was eroded more than 200m in Xuan Thuy district from 1975 to 1989. A part of the beach in the south of Xuan Thuy district was artificially reclaimed. From 1989 to 2001, the beach seems to be stable.

CONCIEVABLE MECHANISM OF SHORELINE CHANGE

Based on the above-mentioned results, it seems that there are two kinds of erosion in the objective site. One is the erosion in the northern part and another is the erosion which is progressing from south to north. These mechanisms of erosion in this region can be explained as follows:

Erosion in north region

In summer season the incident wave from the southeast is dominant and causes the long shore sediment transport to the Balat river mouth. Besides, a huge amount of the sediment is discharged from Balat river to the sea and a large part of the sediment deposits near the mouth. In winter season, the incident wave from the northeast is dominant and the amount of discharged sediment from the river is small because of the dry season. If there is not any thick mangrove forest around the river mouth, these waves transport the deposited sediment in the mouth to the south again. Therefore, the beaches are thought to be stable. These processes are roughly illustrated in Figs. 8 and 9.

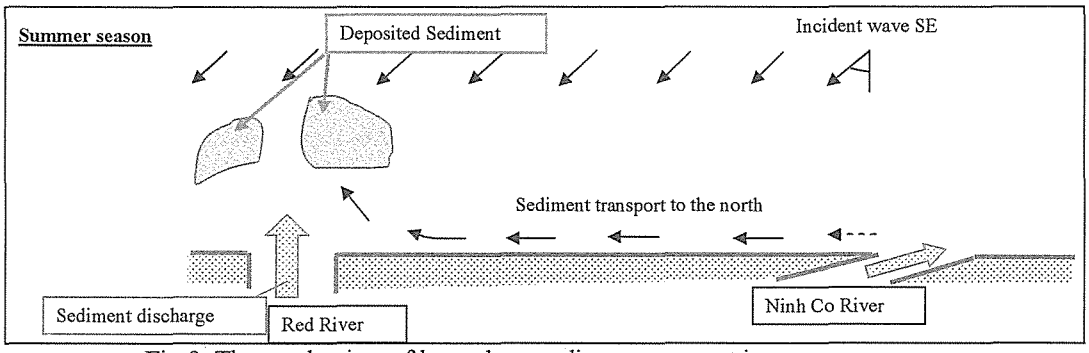

Fig.8. The mechanism of long-shore sediment transport in summer season

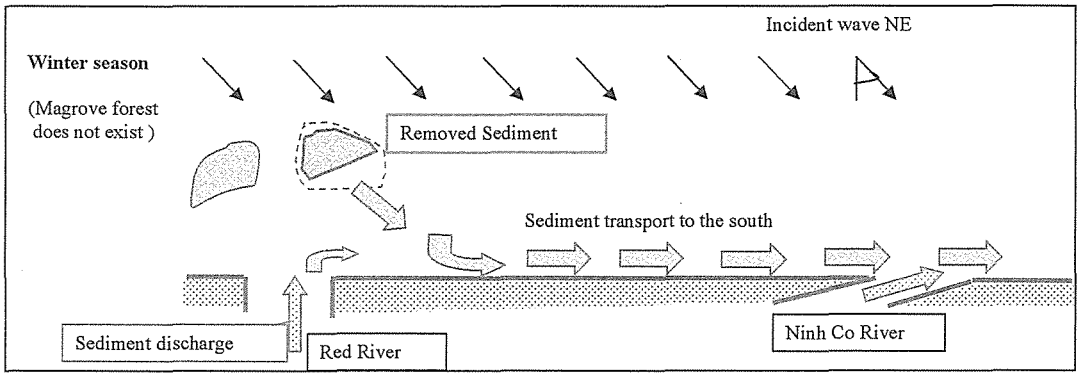

Fig.9. The mechanism of long-shore sediment transport in winter season (without mangrove forest)

However, if there is a thick mangrove forest, it traps sediment within itself and the sediment in the river mouth will not move to the south again and river discharge is also small in winter season. Therefore, the beach will be eroded rapidly.

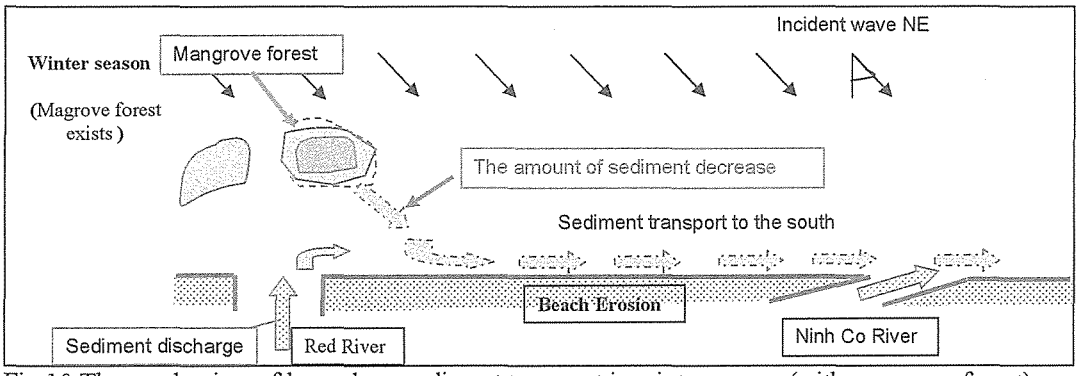

Fig.10 The mechanism of long-shore sediment transport in winter season (with mangrove forest)

Erosion progressing from south to north

As mentioned above, the discharged sediment from Ninh Co river dose not contribute to the shoreline in the southern part of the river mouth where the double sea dike system has constructed. Around the north part of the Ninh Co river mouth, shoreline retreats in winter. However, the retreated shoreline does not recover to the original position in summer due to the unbalance on the longshore sediment transport. This shoreline retreat progresses toward the north.

FOLLOW-UP OF THE TWO MECHANISMS OF EROSION BY ONE-LINE THEORY

Fundamental eruation and boundary conditions

The numerical procedure based on one-line theory is constructed to reproduce two kinds of erosion between Balat river mouth and Ninh Co river mouth

The governing equation is the conservation of sediment equation as following:

$$\frac{\partial Xs}{\partial t} + \frac{1}{Ds}\left(\frac{\partial Q}{\partial y} - q\right) = 0$$

In which Xs is the offshore distance (m); y is the distance alongshore; Ds is the closure depth (m); Q is the volume rate of long-shore sediment transport (m^3/s); q is the rate of sediment entering and leaving the profile from the landward and seaward boundaries ($m^3/s/m$); t is the time (s). The value of Q is evaluated by the following relation:

$$Q = K\frac{\rho g}{16}H_b^2 \sin(2\alpha_b)C_{gb}$$

where ρ is the density of water, g is the acceleration of gravity, H_b, α_b and C_{gb} are the wave height, incident wave angle and celerity at wave breaking point and K is the empirical constant..

According to the previous studies (Ton That Vinh, et al, 1996 and Nagai et al., 1998, Mathers, et al. 1999), following two representative waves are applied:

-In summer, wave height H=2.0m, period T=5.0s, direction ESE, duration six months, with river discharge q=0.002m^3/s.

-In winter, wave height H=1.5m, period T=5s, direction ENE, duration six months, without river discharge q=0.

The boundary conditions applied are shown in Figs.10 and 11. In case where there is a sea dike behind the shoreline, we assume that the distance between the shoreline and the sea dike be 100m and the shoreline can not retreat more than 100m.

When there is a rich mangrove forest at j=js (north boundary) and a large part of sediment is entrapped there, open boundary condition is applied. In case where there is not such mangrove forest at j=js (north boundary), a close boundary condition is applied. At the south boundary (j=je),

there is no sand supply from Ninh Co river in summer and sediment transported toward south is continuous.

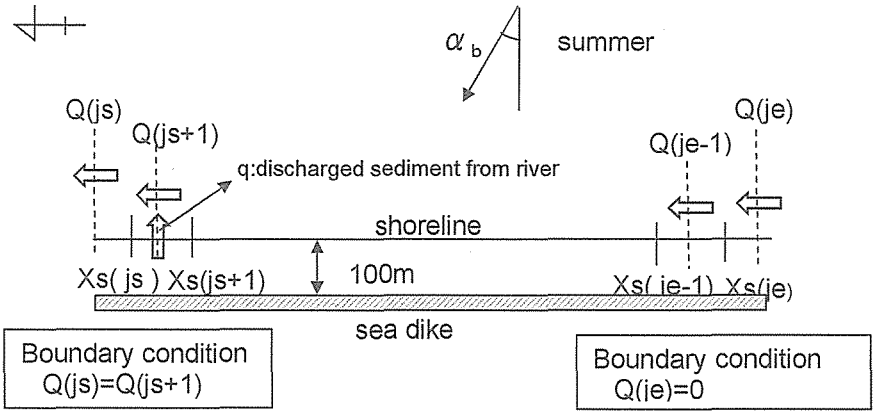

Fig.10 Boundary conditions in summer

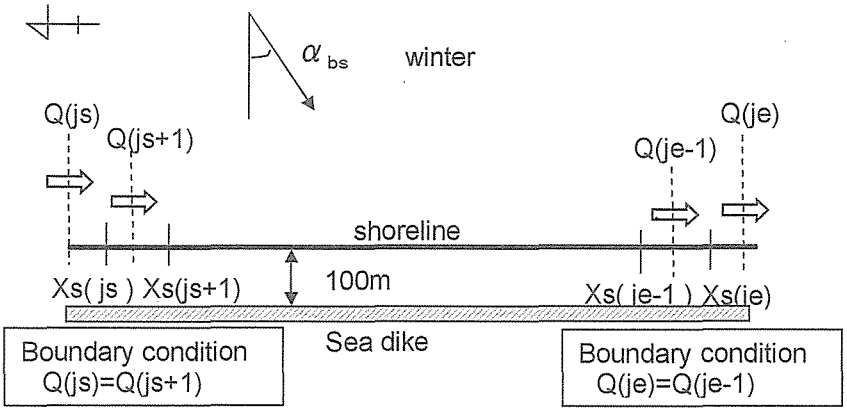

Fig. 11 Boundary conditions in winter

Results of numerical simulations

Figures 12 and 13 illustrate the calculated shoreline change with and without mangrove forest around the river mouth. In the case where the discharged sediment from the river is effectively distributed to the neighboring coast (Fig. 12) the shore line near the river mouth advanced 9km during 150years and the retreat of shoreline at the other end is 4km during 150years. On the other hand, if the all discharged sediment from the river is trapped at the river mouth and is not supplied to the neighboring coast, the location around the shoreline does not change and the retreat of shoreline comes to 5km during 150years.

Figure 14 is the result of the shoreline change backed by a sea dike. In this case, the shoreline can not retreat more than 100m. The shoreline near the south end retreats continuously three years after wave attack. After that, the reason of shoreline retreat progresses toward north at the speed of about 2km/year just like the shoreline retreat shown in Figs.5 and 6.

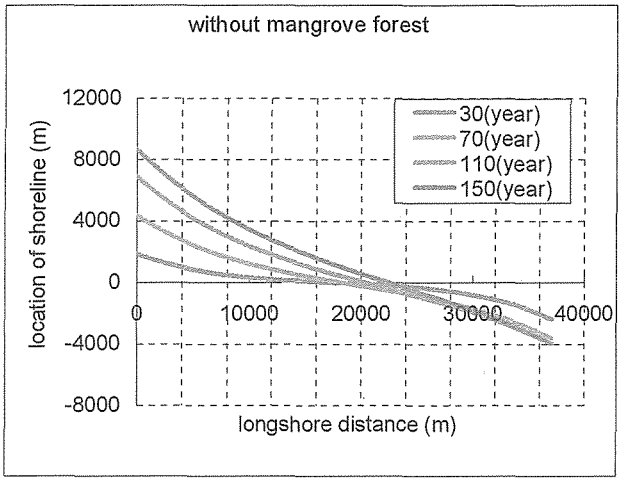

Fig. 12. Calculated shoreline change without mangrove forest

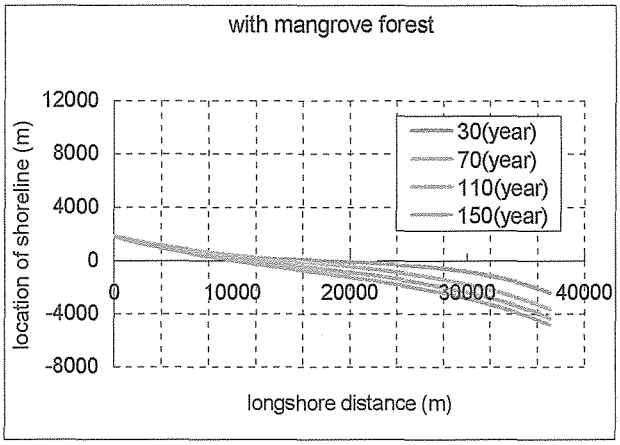

Fig. 13. Calculated shoreline change with mangrove forest

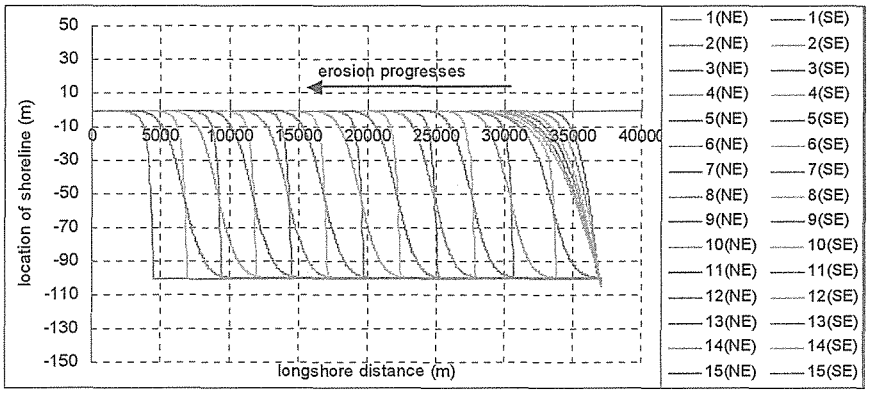

Fig. 14 Calculated shoreline retreat backed by sea dike

From these numerical results, we can judge that erosion between Balat river and Ninh Co river detected from the satellite images can be reproduced by the model with the proper boundary condition qualitatively. It is needless to say that detailed wave and current conditions and beach information are required to increase the accuracy of the numerical simulation.

CONCLUSIONS

By using the parameter $TM_{5\text{-}2}$ proposed in this study, we can detect the location of shoreline from the satellite images effectively. By comparing the detected location of the shorelines for past 30 years, two kinds of erosion were found out and we can reproduce those beach erosions using One-line theory with properly set boundary conditions.
These results will be a great help to work out counter measure against beach erosion.

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