THE INTEGRATION OF GIS AND MATHEMATICAL MODEL FOR SHORELINE PREDICTION

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ABSTRACT: The Coastal area change is problems along the coast of Thailand. There are caused from natural factors and human activities. The coastal area management is need for reduce the damage in Thailand coastal. The shoreline prediction by using the integration of Geo-information technology and mathematical model, this is another way for solve shoreline problem effectively in long term. The aim of the study is to estimate the sediment transportation and shoreline change at Khlong Wan beach, Khlong Wan sub-district, Muang district, Prachuap Khiri Khan Province by using satellite images such as IKONOS 2004, SPOT-5 2007 and Thaichote (THEOS) 2010 integrated with mathematical model. This study area was built a port and breakwaters in 2007.Therefore the objectives of application are to study the change of shoreline during 2004 (before construction condition) to 2010 (after construction condition) and to predict the shoreline in 2020 affected by the construction. The result of the research found that the shoreline was changed near by the wharf and breakwaters construction along the shoreline. The sediment accumulation depended on wave direction which found that the wharf was affected to the decreasing of sediment. The north side of the wharf was eroded. The ten small breakwaters in the northern wharf were affecting to shoreline stability. The crescent shoreline was eroded between the gaps of the breakwaters. Therefore GIS integration with mathematical model will support the coastal zone management effectively because GIS database is powerful information for further monitoring and prediction of the changed shoreline.

1. INTRODUCTION

Thailand's coastline is approximately 2,614 kilometers in length with 1,660 kilometers along the Gulf of Thailand side and 954 kilometers along the Andaman Sea side to cover 23 provinces [1] which differ from one another geographically. Changes are constantly taking place along the coastline areas in the forms of erosion and accretion, with key factors being waves, winds and currents. However, current problems occurring with Thailand's shorelines have accelerated with increased severity, especially concerning changes caused by development activities or structural expansion created by humans, i.e. developments contrasting with the coastal environments, thereby resulting in loss of natural coastal balance and damage to beaches, tourist attractions or various other sites with significance. The government has to allocate a considerable amount of budget for building structures to prevent and restore damaged coastal areas.[2] Examples of preventive structures are sea walls, revetment, headland, breakwaters, groins and jetties.[3] It has been found that some methods for handling coastal erosion may work in one area, but may not work in another. Hence, the first important issue in coastal protection is to gather detailed data on the area and analyze the true causes of the coastal erosion. In this research, Geographic Information System (GIS) and coastal mathematical models are utilized. The two aforementioned technologies are capable of consistency between each other. GIS is for the calibration of basic data and coordinates verification for the mathematical model, which is capable of predicting future shorelines with the construction of any coastal structures, GIS and the coastal mathematical model can be used in solving problems and managing Thailand's coastal erosion problem.

2. METHODS

2.1 Study area

The study area is situated in Klong Wan municipality 10 kilometers from the Muang, Prachubkirikan(Figure 1). The following engineering structures were found to have been built protruding into the sea: a wharf at 420 meters long and 10 meters wide; 1 curved breakwater at 700 meters long in front of the wharf; 12 small breakwaters to the north of the wharf to prevent coastal erosion as a result of the construction of the wharf and a large curved breakwater.

Figure 1 the study area

2.2 Methodology

2.2.1 Data collection and field survey were performed in the study area. Data on sea characteristics and water depth were obtained using an echo sounder attached to the boat running along a designated path. The data acquired was recorded by computer and survey programs every second. Beach profile was surveyed with reference to the horizontal and vertical coordinates of Peg No. GPS389 and GPS390 located at the Klong Wan Bay Fishing Wharf. Sediment samples were collected at depths of 1 and 2 meters to analyze sediment average size and sediment types.

2.2.2 Analysis of previous and current shorelines was performed by using remote-sensing software combination with the GIS program obtained from satellite images, beginning with image resolution resampling to obtain satellite image data with the same pixels, and geometric corrections were performed to obtain satellite images of the actual geographic position. In this research, data from maps of the Royal Thai Survey Department, WGS_1984_UTM_ZONE_47N, were used as the reference point. Image enhancement was performed to emphasize the details of image data. Image classification was performed to interpret coastline data using the visual interpretation method.

2.2.3 The construction of the model can be divided into four main steps: 1) Data preparation and inputting data in the model; 2) Coastal change model processing; 3) Model correction and calibration; 4) Situational coastal change simulation.

2.2.4 Calculation of the area and coastal changes with findings displayed.

2.3 Equation/Mathematical model

2.3.1 LITDRIFT provides a powerful tool for sediment budget analysis, which is of paramount importance to all coastal morphology studies.

$$\tau_b = \frac{d}{dy}\left(\rho E D \frac{dV}{dy}\right) - \frac{dS_{xy}}{dy} + \tau_w + \tau_{cur}$$

(Equation 1 Sediment Transportation (LITDRIFT))

τ_b : bed shear stress due to the long-shore current, ρ : density of water , E : momentum exchange coefficient, D : water depth, V : long-shore current velocity, y : shore-normal coordinate, S_{xy} : shear component of the radiation stress, τ_w : driving forces due to wind and τ_{cur} : coastal current [4]

2.3.2 LITLINE is a powerful and reliable tool design and optimization of many coastal engineering projects, which based upon the results from LITDRIFT

$$\frac{\partial y_c(x)}{\partial t} = -\frac{1}{h_{act}(x)}\frac{\partial Q(x)}{\partial x} + \frac{Q_{sou}(x)}{h_{act}(x)\Delta x}$$

(Equation 2 Shoreline Change (LITLINE))

$y_c(x)$ distance from the baseline to the coastline, t : time, $h_{act}(x)$: height of the active cross-shore profiles, $Q(x)$: long-shore transport of sediment expressed in volumes, x : long-shore position, Δx : long-shore discretization step and q_{sou} : source/sink term expressed in volume/Δx [5]

2.3.3 The erosion and accretion area calculation

Erosion area = (A - (A x B)) (Equation 3)

Accretion area = [(A u B) – (A x B)] – A (Equation 4)

A is the area before change, B is the area after change [6]

2.3.4 The erosion and accretion rate calculation (Figure 2)

Distance is perpendicular with shoreline (meter) = Erosion area (meter^2) / Distance is along the shore (meter) (Equation 5)

The change rate (meter/year) = Distance is perpendicular with shoreline (meter) / Time (year) (Equation 6)

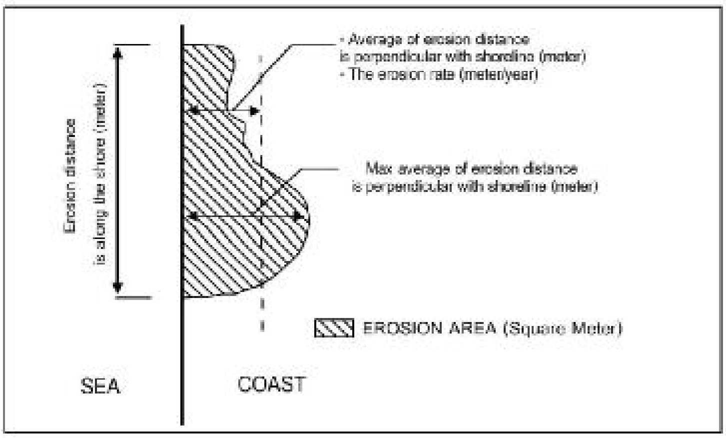

Figure 2 the erosion and accretion rate calculation [7]

3. RESULTS

Coastal changes along the 3800-meter shoreline of Klong Wan comprised a Bathymetry map, sediment size, wave rose map, beach profile, net annual sediment and previous time shoreline. This data were used as input data for the mathematical model, the results of the calibration testing model, shoreline change model and areas with shoreline changes.

3.1 Shorelines from the Mathematical model

3.1.1 The shoreline of 2010 in cases where there were no constructions of structures used the shoreline of 2004 acquired from satellite image data as the starting shoreline (Figure 3).

Figure 3 the shoreline of 2010 in cases where there were no constructions of structures.

3.1.2 The shoreline of 2020 in cases where coastal structures remained present used the shoreline of 2010 acquired from satellite image data as the starting shoreline (Figure 4).

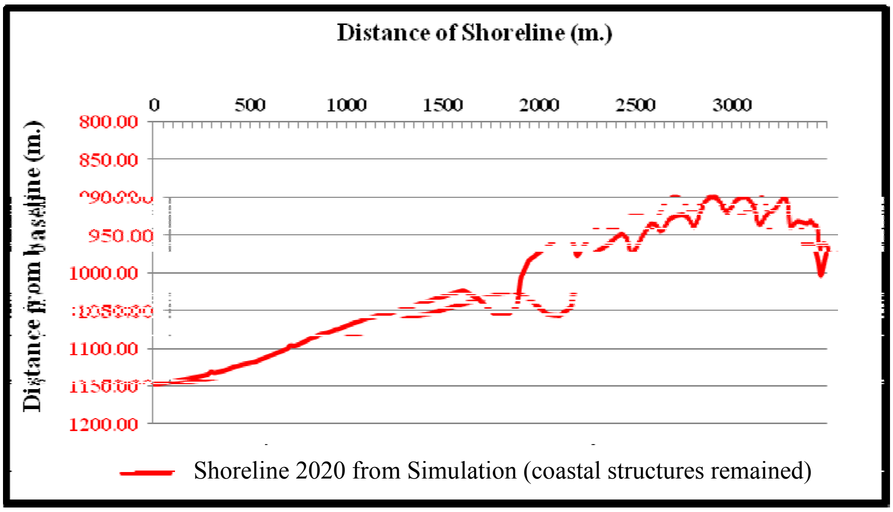

Figure 4 the shoreline of 2020 in cases where coastal structures remained present.

3.1.3 The shoreline of 2020 in cases where all coastal structures had been removed used the shoreline of 2010 acquired from the satellite image data as the starting shoreline (Figure 5).

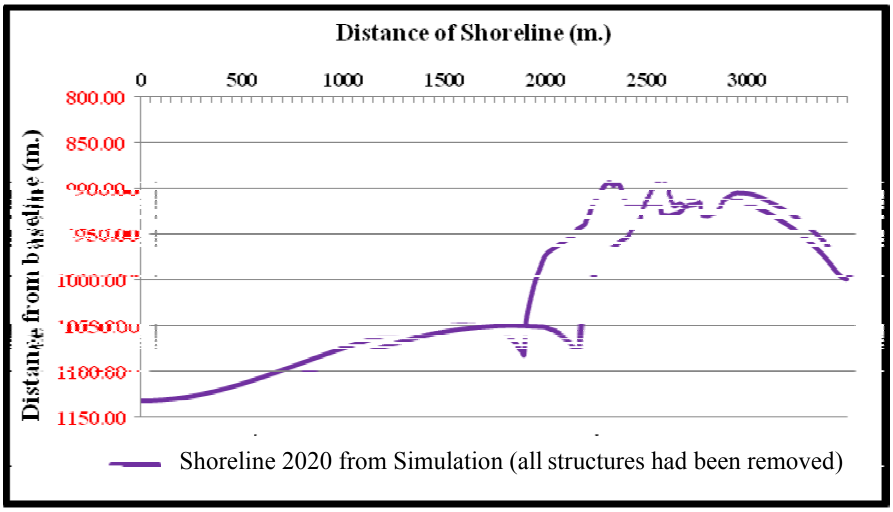

Figure 5 the shoreline of 2020 in cases where all coastal structures had been removed.

3.2 Coastal Change Analysis Results

1. Concerning the 2010 coast in cases where there were coastal structures and when the shoreline of 2004 acquired from satellite image data was used as the starting shoreline to calculate changes to shoreline changes with the shoreline of 2010 acquired from satellite image data, the study area was found to have an area of erosion of 6,014.65 square meters, an accretion area of 19,566.85 square meters, an average erosion rate of 0.93 meters per year and an average accretion rate of 1.99 meters per year (Table 1).

2. Concerning the coast in 2010 in cases where no structures had been built and when the shoreline of 2004 acquired from satellite image data was used as the starting shoreline to calculate changes to shoreline changes with the shoreline of 2010 acquired from simulation with a model, the study area was found to have an erosion area of 1,091.39 square meters, an accretion area of 15.45 square meters, an average erosion rate of less than one meter per year and an average accretion rate of less than one meter per year.

3. Concerning the coast in 2020, in cases where coastal structures were present and when the shoreline of 2010 acquired from the satellite image data was used as the starting shoreline to calculate changes in shoreline changes with the shoreline of 2020 acquired from simulation with a model, the study area was found

to have an erosion area of 20,385.07 square meters, an accretion area of 20,542.18 square meters, an average erosion rate of 2.13 meters per year and an average accretion rate of 1.86 meters per year (Figure 6).

4. With regard to the coast in 2020 in cases where all coastal structures had been removed and when the shoreline of 2010 acquired from satellite image data was used as the starting shoreline to calculate changes to shoreline areas with the shoreline of 2020 acquired from simulation with a model, the study area was found to have an erosion area of 8,143.55 square meters, an accretion area of 2,404.26 square meters, an average erosion rate of 0.77 meters per year and an average accretion rate of 0.21 meters per year (Figure 7).

Table 1 Coastal Area Change

Coastal Area Change					
Year	Scenario	Erosion Area (Square Meter)	Accretion Area (Square Meter)	Erosion Rate (Meter/Year)	Accretion Rate (Meter/Year)
2004-2010	structure	6,014.65	19,566.85	0.93	1.99
	No structure	1,091.39	15.45	0.00	0.00
2010-2020	structure	20,385.07	20,542.18	2.13	1.86
	No structure	8,143.55	2,404.26	0.77	0.21

Figure 6 the coast in 2020, in cases where coastal structures were present and when the shoreline map.

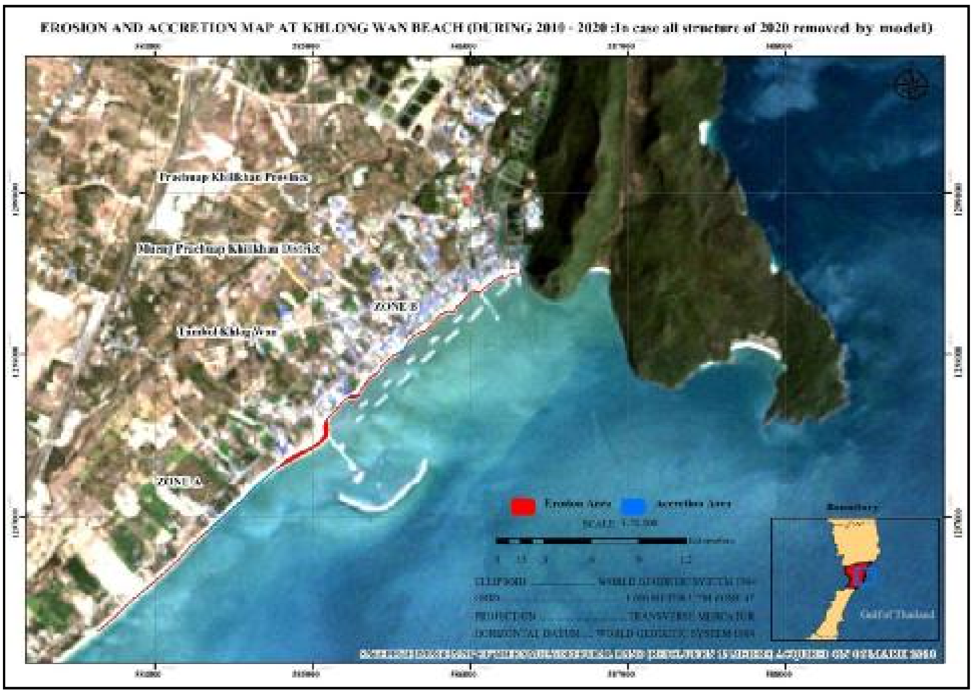

Figure 7 the coast in 2020 in cases where all coastal structures had been removed map.

4. CONCLUSION

According to the study, use of mathematical models to predict shorelines was highly beneficial and greatly increased the efficiency of models when implemented with the Geographic Information System (GIS) because the GIS helped correct basic data and confirmed coordinates for mathematical models for greater predictive accuracy. The findings of this study demonstrate that shoreline changes caused by construction along the shoreline will cause changes only to the areas adjacent to or near the structures, especially regarding accretion of sediments, which will be dependent on the direction of currents. If structures obstruct sediments moving according to the flow of currents, i.e. in this study where the wharf was found to have characteristics of being a groin for collecting sediments, there will be deficient sand sediment and erosion will occur on the side where coastal currents flow, i.e. the north side of the wharf. Furthermore, there were also ten small breakwater dams to the north of the wharf, causing the beach to the north of the breakwaters to lack stability and undergo erosion with crescent-shaped indents along the gaps between the breakwaters. Other areas either nearby or adjacent to structures will change according to normal factors in nature.

5. RECOMMENDATIONS

The recommendations for implementation of the Geographic Information System with mathematical models to predict shorelines in this study were as follows:

5.1 Due to limitations on the issue of research funding, field data was collected only once in order to represent data for entry into the model. Therefore, additional data should be collected to represent two more seasons, during the southwestern and northeastern monsoon seasons, in order to enhance the accuracy of the model.

5.2 This study entered wave data into models to calculate sediment direction and movement. Wave data was acquired from WAM models of the Thai Meteorological Department, which was data on deepwater waves approximately twenty kilometers from the coast. Therefore, wave data which can be measured from shallow waters near to the coast which were waves with the most impact on coastal areas should be collected. However, Thailand has no wave data which can be directly measured in this way to increase the precision and accuracy of the model.

5.3 A number of methods are available for managing coastal zones with good effects, depending on the characteristics of the areas with problems and each method has both advantages and disadvantages. Therefore, consideration of available options for planning management, prevention and problem-solving must analyze related data completely and thoroughly together with consideration given to suitability, engineering, economic, social and environmental feasibility together with the aspects of techniques and various methods, such as advanced engineering to methods of indigenous wisdom/intellect in order to acquire various methods for solving problems. Furthermore data, knowledge and exchanges of experience should be disseminated among persons in various fields of knowledge in the government, private and public sector who are involved as stakeholders, so options can be considered for the prevention and solution of problems from coastal changes in line with the needs of coastal communities.

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