Simulation of benefits of coastal mangrove in erosion prevention in U-Minh beach, using Telemac2d (flow simulations), Tomawac (wave conditions) and Sisyphe (sediment simulations)

1. Introduction

In order to reduce the impact of erosion in coastal areas in Vietnam, one of solutions is to plant the coastal mangroves. The expected effect of the mangrove is to change the hydrological and wave regime by decreasing intensity, thereby reducing the risk of erosion in the area covered by mangroves.

Figure 1.1a: A type of coastal mangrove for shore protection

Figure 1.1b: A type of coastal mangrove for shore protection

In this study, numerical models applied simultaneously the module Telemac2D (flow simulations), module Tomawac (wave conditions) and module Sisyphe (sediment simulations). This allow to simulate the effects of mangrove forests on hydrodynamic and wave regimes through certain parameters such as porosity, plant density, typical diameter, friction coefficient, resistance caused by mangrove, ...

2. Simulation of initial condition of local area in U-Minh and boundary conditions

The local area of interest is the western coastal area of the Mekong Delta, with the average width of 40 km from the coast and 126 km from Ca Mau Cape to the north. This study area is characterized by 87 thousand unstructured triangle elements of which the largest mesh is up to 2000m (offshore elements) and the smallest is 12m for the coastal zone.

In order to assess the impact of coastal mangrove forests on coastal accretion and erosion, we consider a typical mangrove area which is 250m in width (B) and 7000m in length (L). This area locates between Bay-Hap and Ong-Doc rivers.

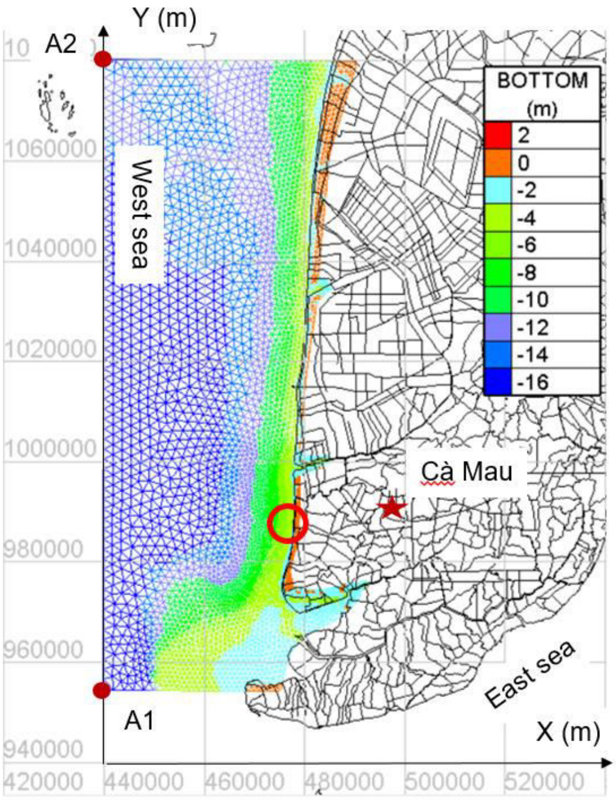

Figure 2.1a: Study zone

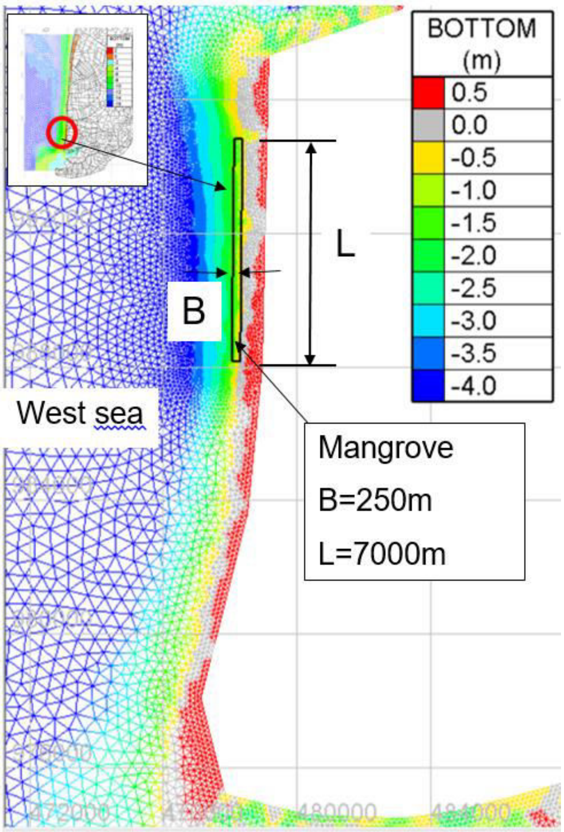

Figure 2.1b: Simulation of mangrove in study area

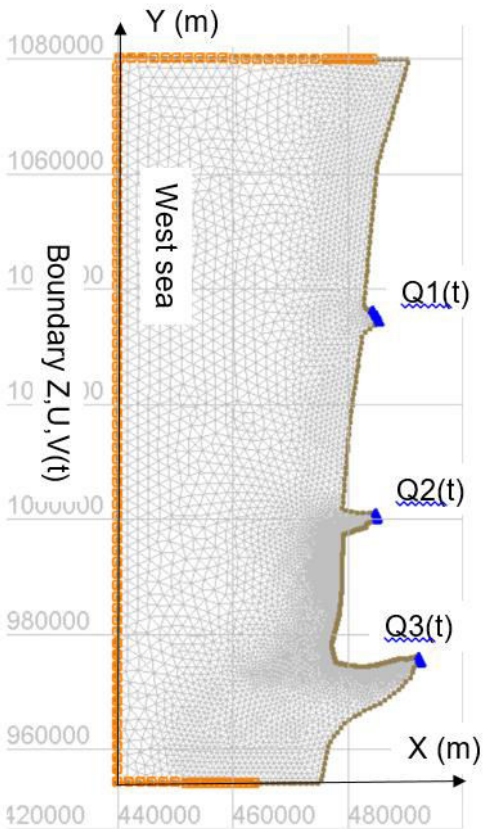

Figure 2.2: Boundary conditions

Tidal

The open boundary at offshore is determined from astronomical tide extracted from TPXO database during the study period.

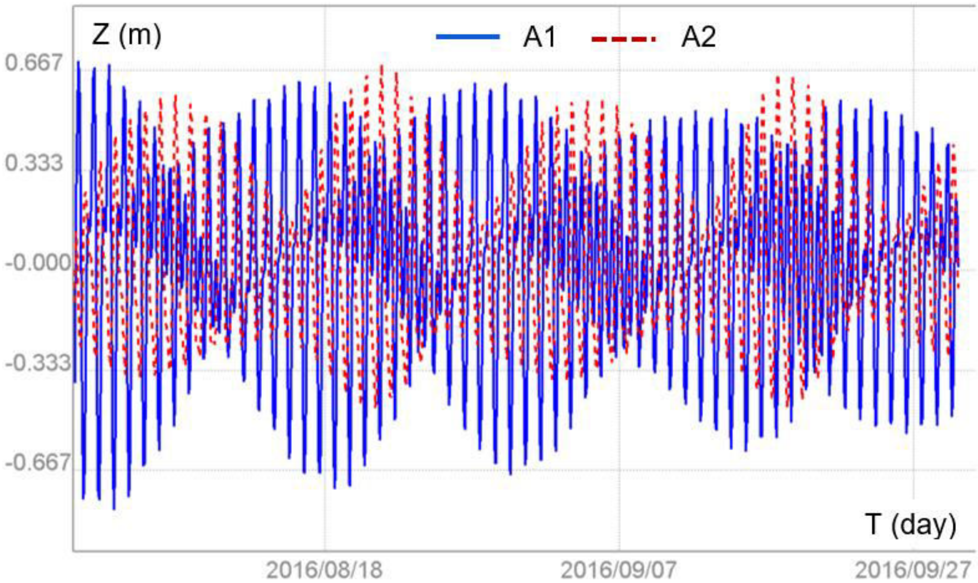

Figure 2.3: Tidal boundary at typical positions A1 and A2 during Aug. & Sep 2016

Wave

At the open boundary, wave data is determined from a global database of wind and wave effects on the surface domain determined from NOAA for the boundary conditions of the Tomawac model.

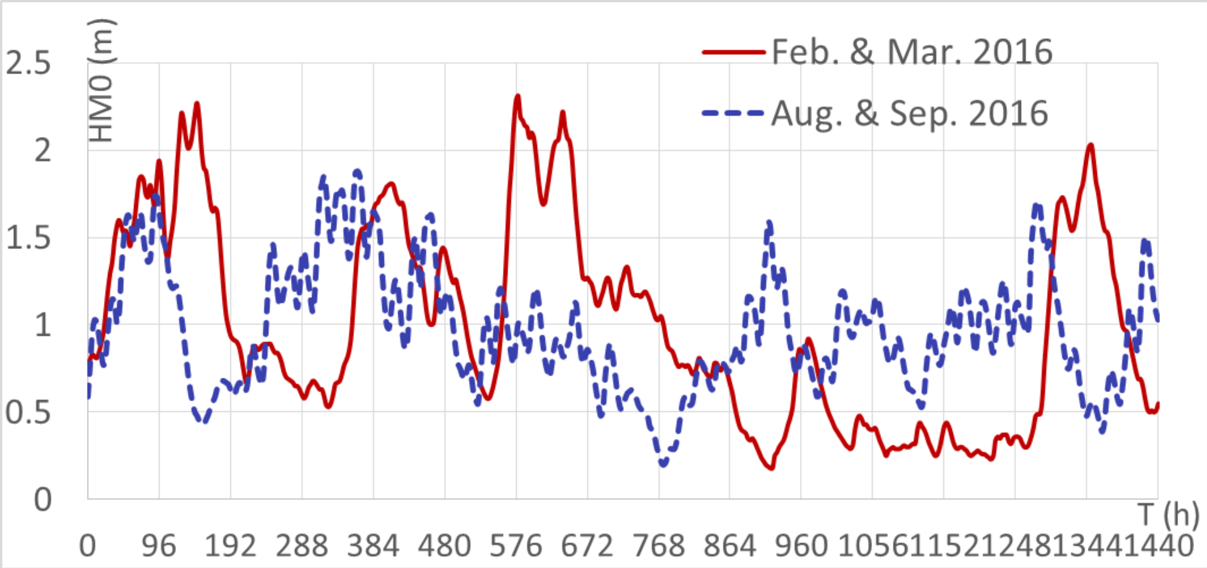

Figure 2.4a: Wave height HM0 from NOAA at coordinates (334682.9 ; 884599.1)

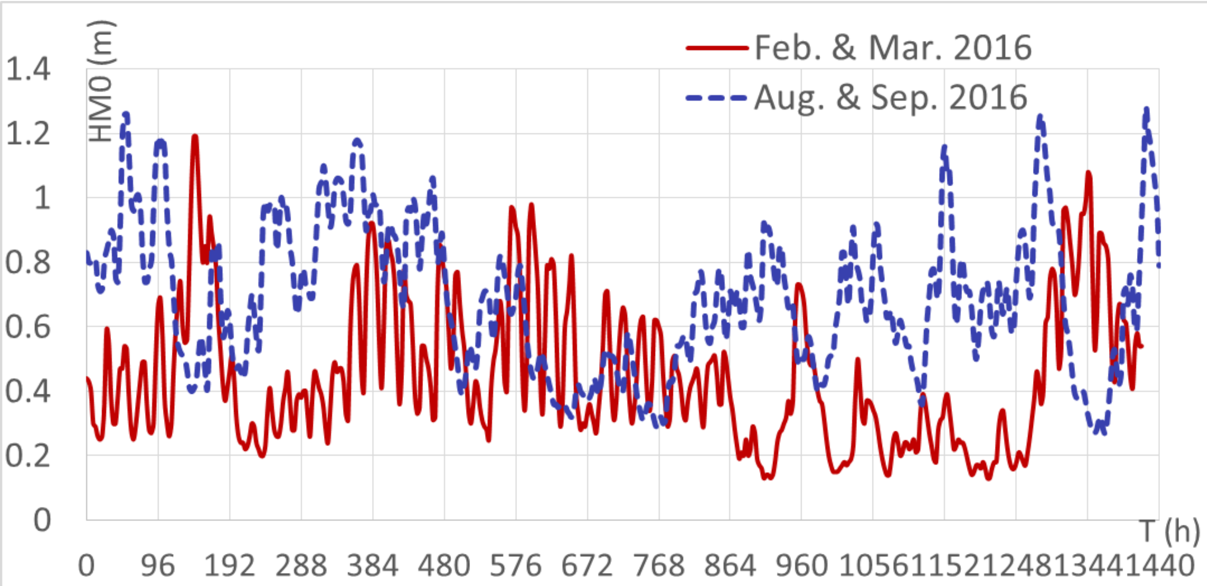

Figure 2.4b: Wave height HM0 from NOAA at coordinates (335343.7 ; 1050487.3)

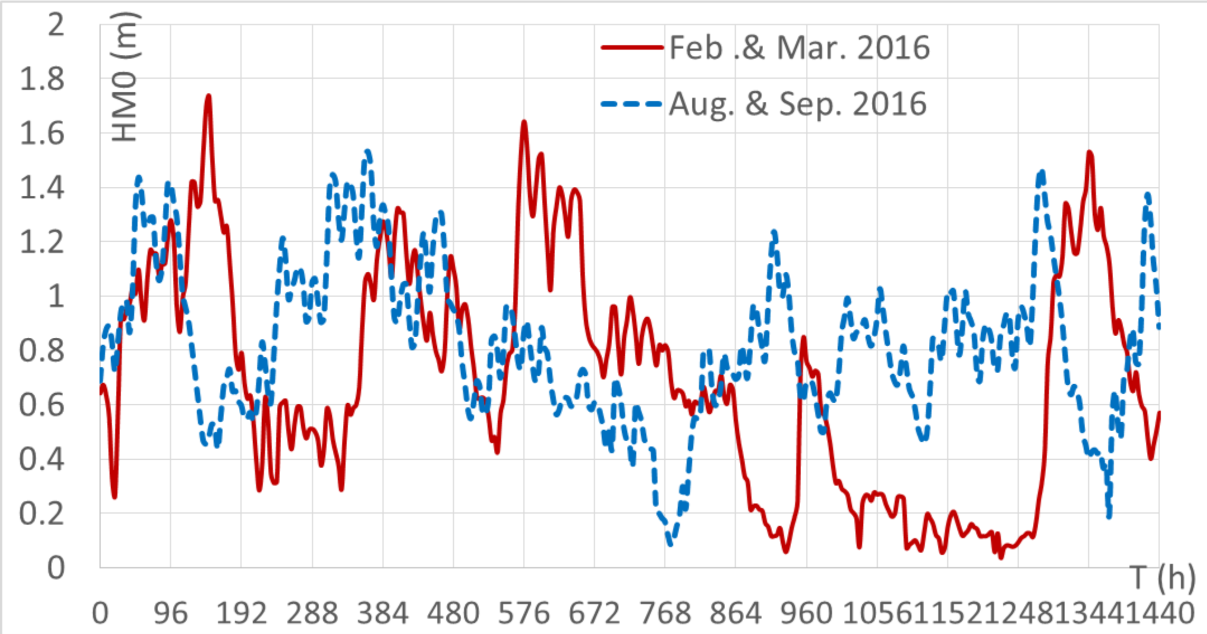

Figure 2.4c: Wave height HM0 from NOAA at position A1 of coordinates (439869.6 ; 954419.1)

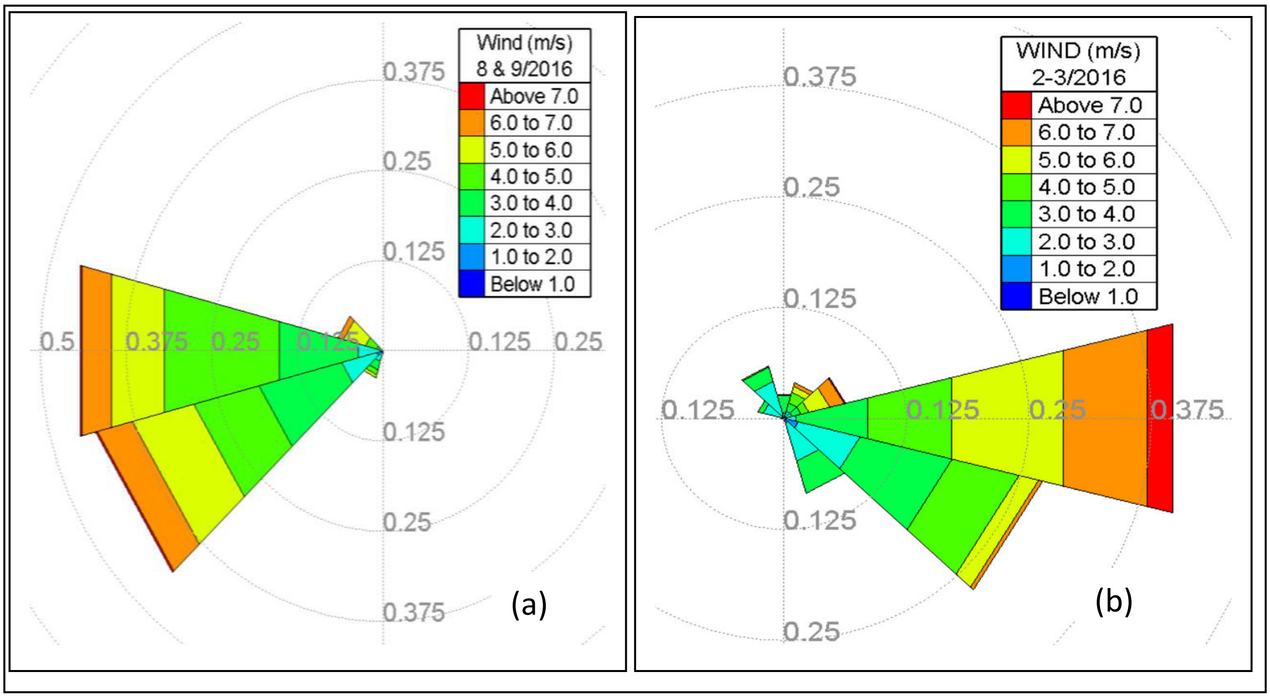

Figure 2.5: Typical wind rose in U-Minh coast in: (a) 8-9 /2016 and (b) 2-3/2016

The results from the wind rose show that these are two distinctly monsoonal periods. In the months of February and March, the winds are relatively intense compared to August and September. Wind direction in February and March is mainly from the East, while in August and September, it is mainly in the west and southwest.

Discharge

Discharge in Ong-Doc river are taken as follow:

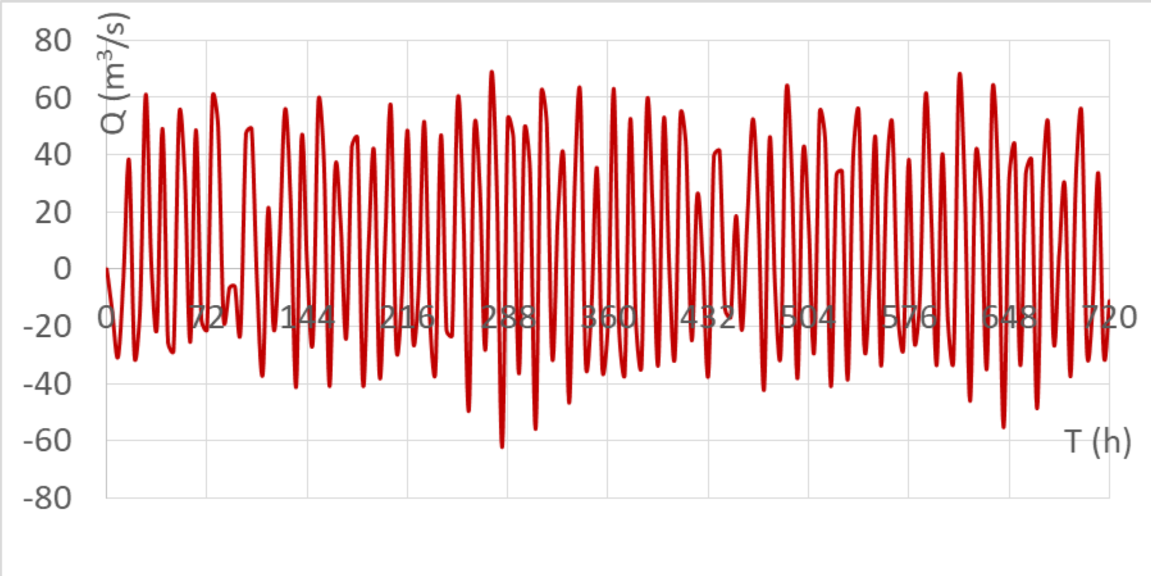

Figure 2.6: Discharge in Aug 2016 at Ong-Doc river

Sediment

Simulation of sediment transport in the area is considered as non-cohesive transport. The distribution of sand is assumed to be uniform throughout the study area. From the monitoring data of granular, the particle size is divided into four representative sizes: 0.06mm, 0.125mm, 1.0 mm, 1.5mm; with the initial rates of 40%, 30%, 20% and 10%. The friction law is set as Nikuradse law.

The boundary conditions are:

- The open offshore boundary is free and balance condition.

- In the upstream areas, the boundary conditions are specified of Direclet type with the monitoring level.

The main parameters of simulation are as follows:

- The law of friction according to Nikuradse

- The bottom sediment transport model according to Soulsby - Van Rijn

- The settling velocity is determined by the Van Rijn, depending on the characteristic of the sediment layer.

- The value of the Shields taken by the Rijn Valves depends on the dimensionless dimension of the sediment classes.

3. Simulation results of sediment transport under effect of mangrove

Simulations are made for two representative seasons: the southwest monsoon season and the northeast monsoon season. Each simulation season lasts for 2 months:

- West-South monsoon season: 8-9 / 2016

- East - North monsoon season: 2-3/ 2016

Simulations of mangroves with average width from the shoreline are B = 250m, L = 7000m in length for two cases:

Case 1:

- Mumber of plants per m^2: 6
- The height of trees: 1 (Equal to highest water level)
- Plant area per unint height: 0.2
- Mean diameter of the tree: 0.2
- Bulk drag coefficient: 0.2
- Porosity: 0.90

Case 2:

- Mumber of plants per m^2: 10
- The height of trees: 1 (Equal to highest water level)
- Plant area per unint height: 0.3
- Mean diameter of the tree: 0.2
- Bulk drag coefficient: 0.3
- Porosity: 0.85

The simulation of sediment transport is performed from the simultaneous combination of three equations: hydrodynamics, wave and morphology. Discharge boundary at offshore is set as free boundary for bed load and suspension. Due to limitation of bathymetry data, the model only considers some confluents such as Bay Hap, Ong Doc. The concentration of suspended sediment at the confluents is set as 100 mg/l.

Under the regime of hydraulic and wave in U Minh coast, satellite data on suspended sediment for a typical month was recorded as follows:

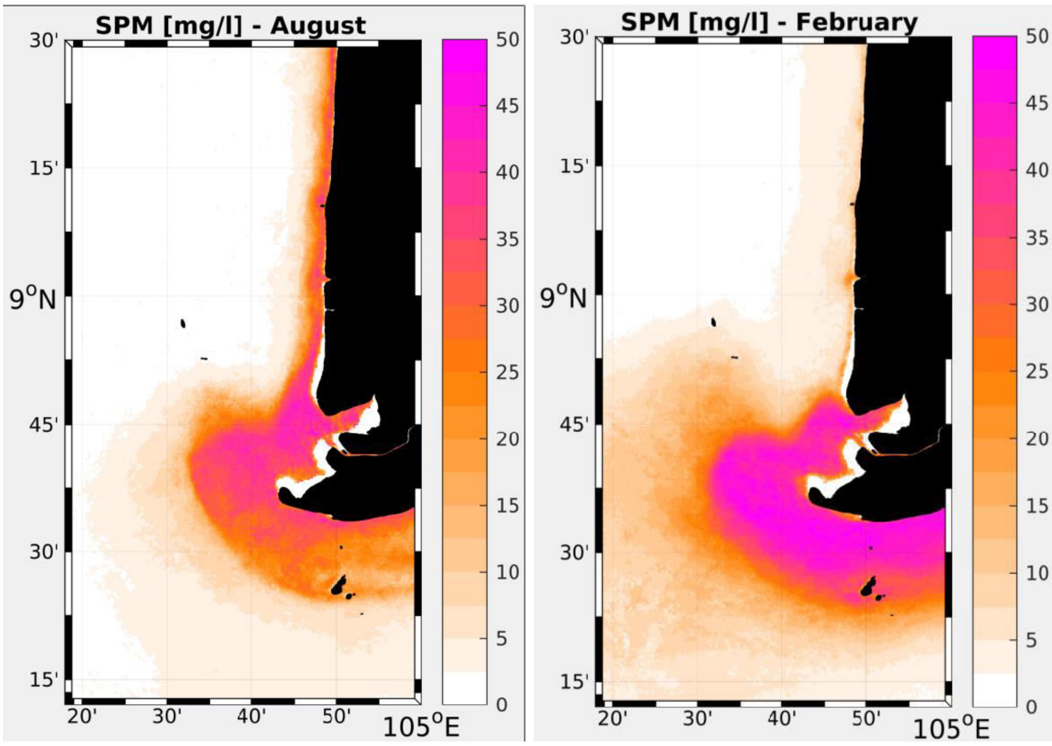

Figure 3.1: The typical average concentration of suspended sediment in August and February 2016 from the satellite data

The above picture shows clearly the effect of coastal break waves on the concentration of suspended sediment in the area. To quantify the sediment transport in the mangroves, the results of sediment budget analysis in the study area (including mangroves) with a width of B = 800m, length L = 7000m (Fig. 2) will be discussed.

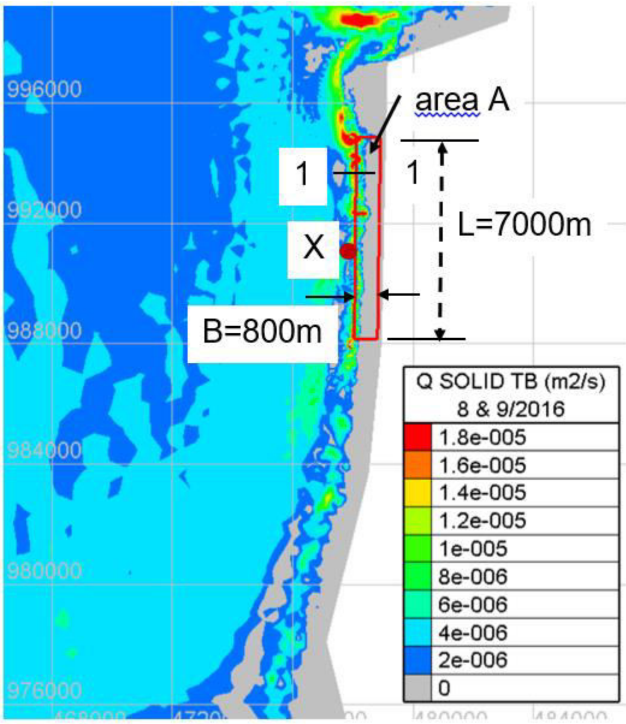

Figure 3.2: Position of zone A for sediment budget analysis

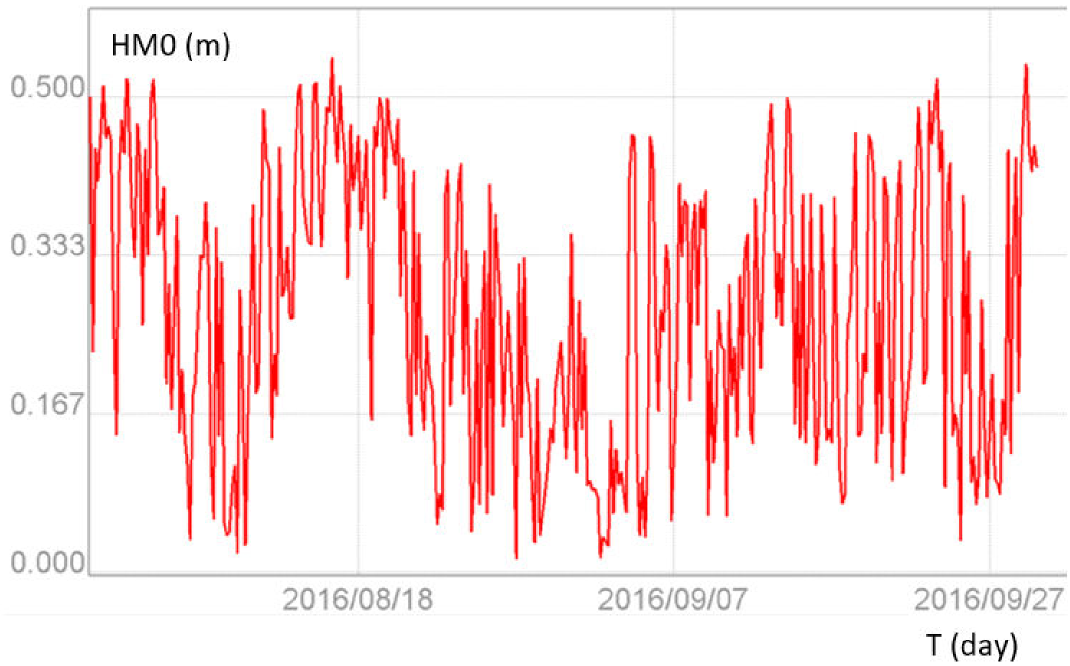

Figure 3.3: Wave height HM0 (m) at typical position X in 8-9/2016

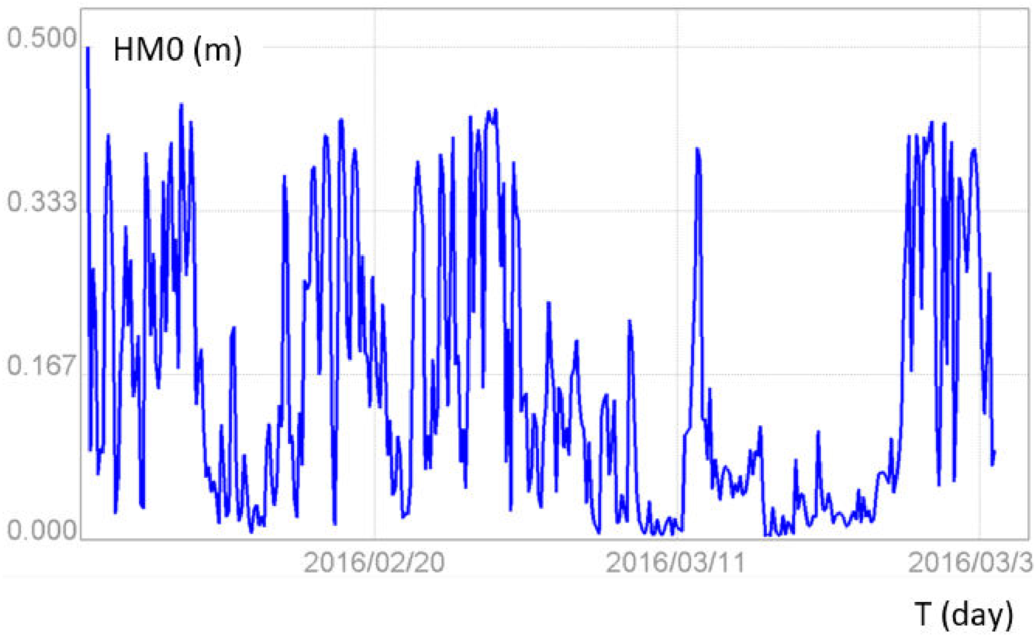

Figure 3.4: Wave height HM0 (m) at typical position X in 2-3/2016

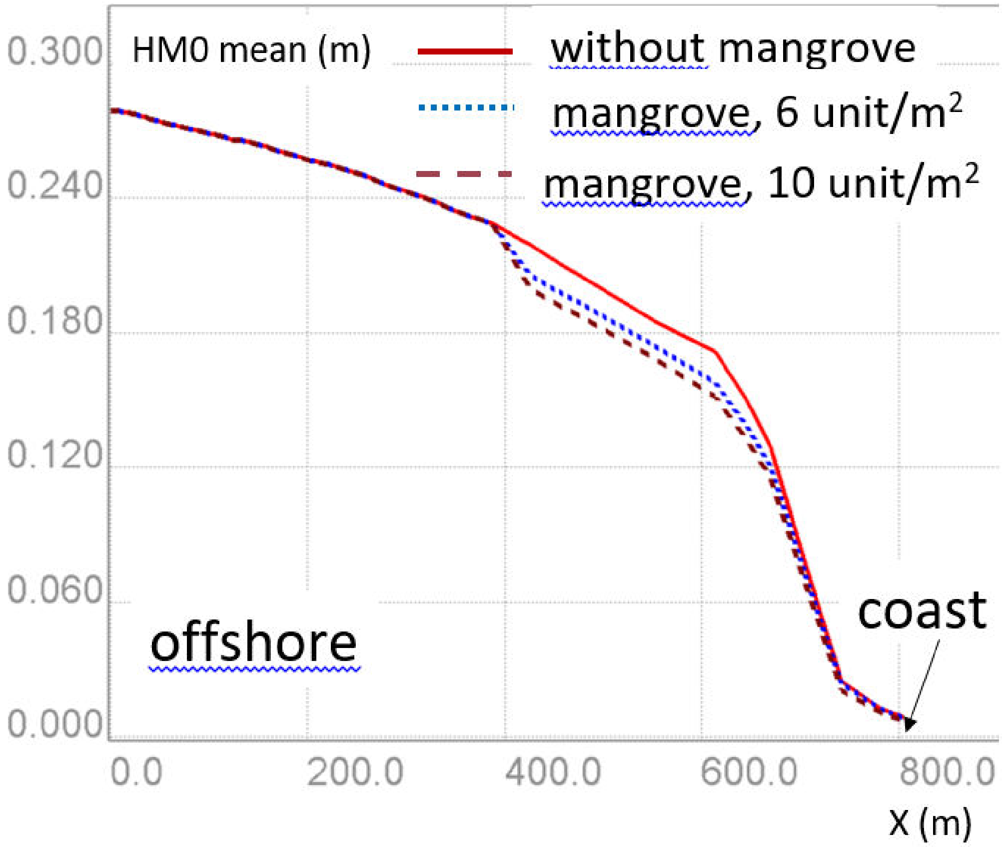

Figure 3.5: Average wave height HM0 (m) in 8-9/2016 at section 1-1

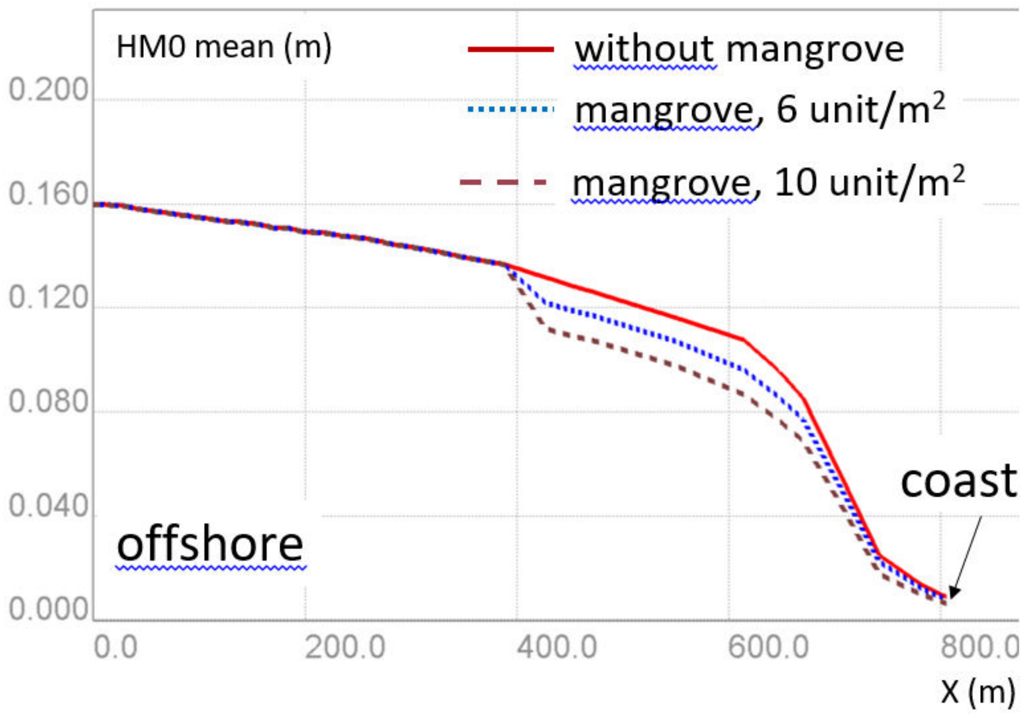

Figure 3.6: Average wave height HM0 (m) in 2-3/2016 at section 1-1

The results in Figures 3.3 and 3.4 show that the waves in the August-September 2016 are larger than those in February-March 2016 at the location X. This corresponds to the wind intensity at these times. Comparison of the results in Figures 3.5 and 3.6 gives the following main conclusions:

- The effect of wave attenuation from mangroves is significant within the range B = 250m near the shore.

- The density of mangrove is proportional to the reduction of HM0 wave. This result demonstrates the possibility of reducing erosion in mangroves that will be quantitatively determined at the next section.

The following results compare the erosion at site A (Figure 3.2) between three cases of different densities: 6 trees/m^2, 10 trees/m^2 and without mangroves, and is summarized in the following table.

Table 3.1: Sediment budget analysis at coastal area in 8-9/2016

Case	In (m^3)	Out (m^3)	(In-Out) (m^3)	Comment
Without mangrove	94.1	242.3	-148.2	(+) accretion
Mangrove B=250m, density 6 tree/m^2	93.6	216.2	-122.6	(-) erosion
Mangrove B=250m, density 10 tree/m^2	93.2	216.0	-122.8	

Table 3.2: Sediment budget analysis at coastal area in 2-3/2016

Case	In (m^3)	Out (m^3)	(In-Out) (m^3)	Comment
Without mangrove	302.1	375.2	-73.1	(+) accretion
Mangrove B=250m, density 6 tree/m^2	300.8	341.3	-40.5	(-) erosion
Mangrove B=250m, density 10 tree/m^2	303.1	312.2	-9.1	

Comment: Based on the sediment budget analysis at the study area (see Figure 3.2), the following comments are deduced:

- The mangrove forest has the effect of reducing erosion in the corresponding area.

- The erosion decreases as the density of plants increases (compare two cases with a density of 6 trees/m^2 and 10 trees/m^2). This result is explained by the reduction in wave energy of the densities with higher plant densities and hence the partial reduction of shoreline erosion.

- The coastal erosion in 8-9/2016 is slightly larger than in 2-3/2016. This result can be explained by the relative high intensity of wave intensity at this times.

4. Simulation results of sediment transport with the presence of mangrove and nourishment beach

The previous report related to the effects of nourishment beach in wave attenuation and erosion protection in U-Minh coast has been shown. In this section, simulation of scenario using simultaneously nourishment beach and mangrove protection will be performed.

The project has the following main parameters:

The width of nourishment is B1 = 120m, the height is H = 1.7m and the length is L = 7000m. This zone is parallel to the shore with an average offset of 800m to 1000m.

The coastal mangrove is B2 = 250m in width, and L = 7000m in length, with the average density is 10 trees/m^2.

Simulations are made for two representative seasons: the southwest monsoon season and the northeast monsoon season. Each simulation season lasts for 2 months:

- West-South monsoon season: 8-9 / 2016

- East - North monsoon season: 2-3 / 2016

The following results show the wave reduction effect of the structure as well as the erosion effect of the considered area:

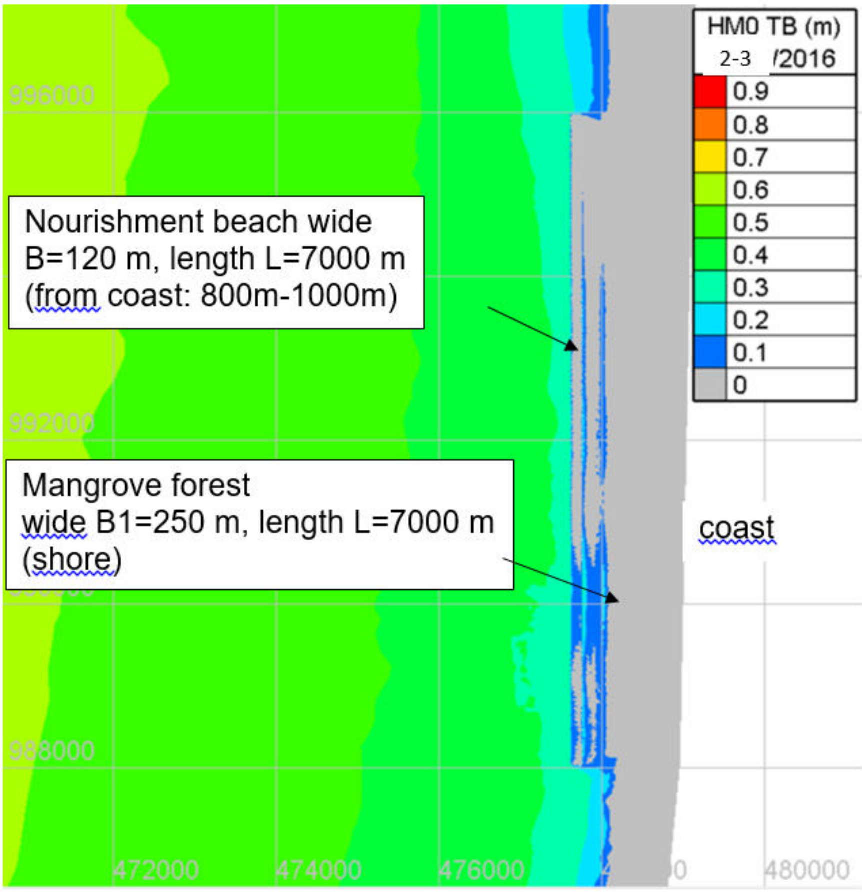

Figure 4.1: Wave height HM0 (m) in 2-3/2016 at study area

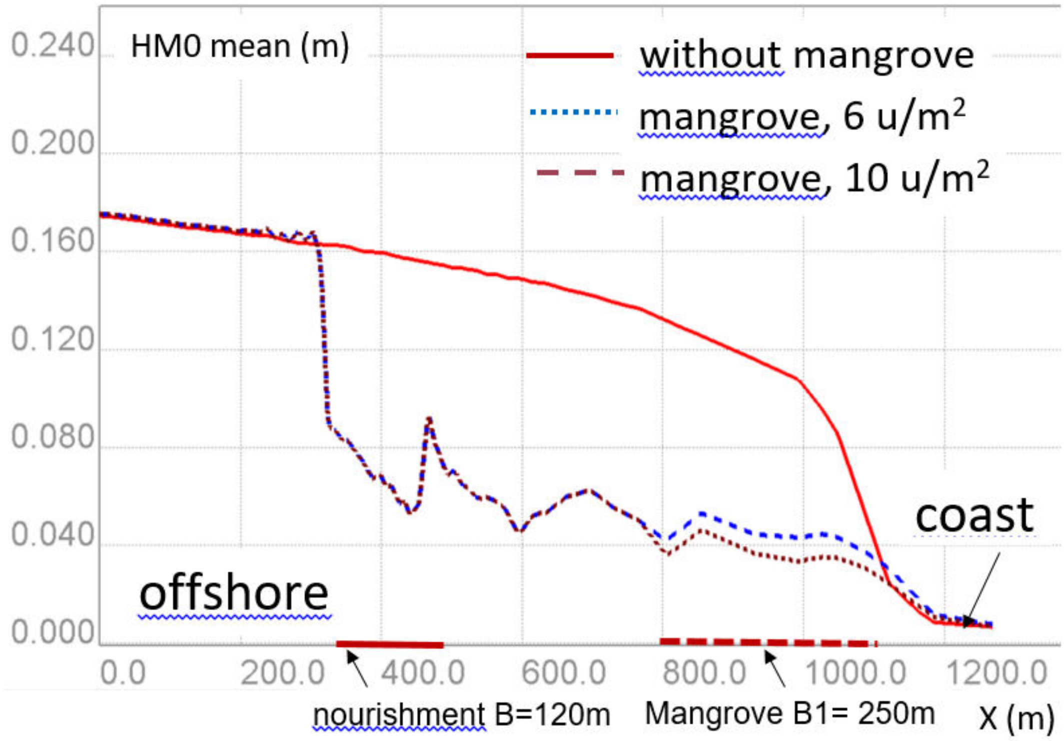

Figure 4.2: Wave height HM0 (m) in 2-3/2016 at section 1-1

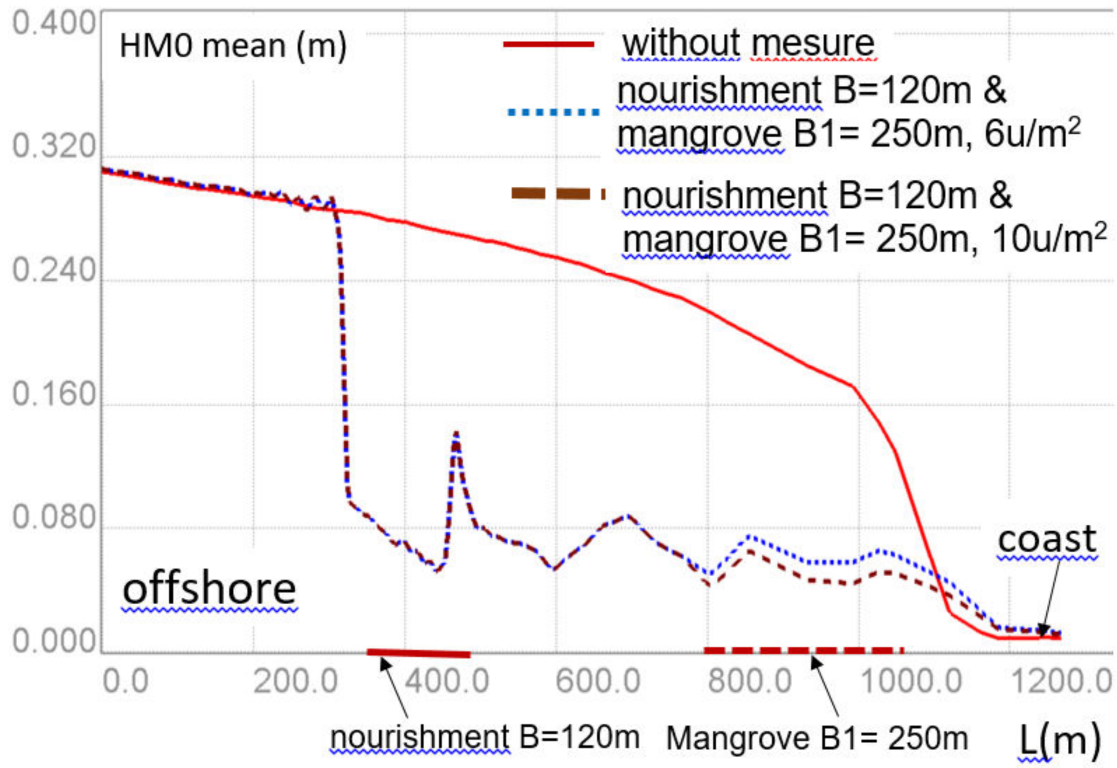

Figure 4.3: Wave height HM0 (m) in 8-9/2016 at section 1-1

The results of the above two graphs show the capacity of wave attenuation using combination of the two solutions. Comparing the reduction in average HM0 wave height on typical cross-section 1-1 between different cases shows that wave propagation to near-shore areas was first reduced significantly crossing the nourishment beach with a width of B1 = 120m and then reducing the waves when entering the mangrove forest with less wave reduction. Relatively, the average value of HM0 waves is reduced to about 1/3 compared to the absence of nourishment beach and the average HM0 decreases by about 1/2 in case of having mangrove forest.

In order to quantitatively assess the erosion effect of the above calculation scenarios, the following tables show the general calculation of sediment balance in typical A-domain in the area as follows:

Table 4.1: Sediment budget analysis at section A in 8-9/2016

Case	In (m^3)	Out (m^3)	(In-Out) (m^3)	Comment
Without mangrove	94.1	242.3	-148.2	(+) accretion
Mangrove B=250m, density 6 tree/m^2	109.4	3.9	105.5	(-) erosion
Mangrove B=250m, density 10 tree/m^2	110.7	2.3	108.4	

Table 4.2: Sediment budget analysis at section A in 2-3/2016

Case	In (m^3)	Out (m^3)	(In-Out) (m^3)	Comment
Without mangrove	302.7	375.6	-72.9	(+) accretion
Mangrove B=250m, density 6 tree/m^2	314.1	7.2	306.9	(-) erosion
Mangrove B=250m, density 10 tree/m^2	315.4	3.6	311.8	

The above tables show the positive effect of the combination of two solutions. The results show that with the simultaneous consideration of nourishment and mangroves, the study area has the accretion (with positive value) compared to the other cases with erosion (negative value) with different levels of erosion.

5. CONCLUSIONS

Simulations have been made for coastal mangrove solutions in erosion prevention. The impacts of the mangrove forest on sediment transport in U-Minh are carried out in two representative periods of 2-3/2016 and 8-9/2016. Different plant densities are also taken into account. Some main conclusions have been made:

- Waves are an important cause of erosion in the U-Minh coast.

- The mangrove forest has the effect of reducing coastal waves, thus reducing erosion in the coastal area.

- Larger plant density has more effect in reducing erosion.

- The combination of coastal mangroves and nourishment beach is more effective.

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