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Situation, causes and solutions for coastal protection and restoration of coastal mangroves in the Mekong Delta

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Abstract: The system of mangrove belt and seadike in the Mekong Delta plays an important role in protecting the behind land againts natural disasters from the ocean, increasing sediment deposition along the coast, as well as protecting environment, biodiversity, and biological systems. Unfornately, the mangrove forest in the Mekong Delta has been seriously degrading in recent decades, even completely disappeared at several areas. Coastal erosion has damaged houses, infrastructures (i.e seadike, road,…), properties of people living in the coastal area. By analysing historical data, remote sensing datain several years and also by using numerical and physical models, the change of coastline and the main causes of coastal erosion were carried out, from which the feasible solutions for coastal erosion protection and mangrove forest restoration for the Mekong delta coast were proposed.

Key words: erosion; mangrove degradation; lower Mekong Delta

I. Introduction

The Mekong Deltain Vietnamcovers an area of 39,734 km². TheDelta was formed from sediment deposition through the changing sea level. The participation of the Mekong River plays a very important role during the lower and delta formation of Mekong delta. The river's annual average volume of water supplies about 400 billion m³ along with more than 100 million tons of sediment(Morgan F. R., 1961). Undergoing the evolution, change and adaptation cycles between the sea and the mainland, the coastal plain of the Mekong delta has emerged as a transitional ecosystem - coastal mangrove strip with biodiversity with 98 species of plants in which common species are Avicennia alba, Rhizophoraceae,Sonneratia alba, Sonneratia caseolaris, Bruguiera, Ceriops decandra, Ceriops tagal,bean sprout, Bruguiera parviflora, Spondias dulcis, Nypa fruticans and many others besides 182 species of birds, 34 species of reptiles and 6 species of amphibians, and 260 species of fish [1].

The coastal plain of the Mekong Delta is located in seven provinces: Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau and Kien Giang, with a length of about 774 km.

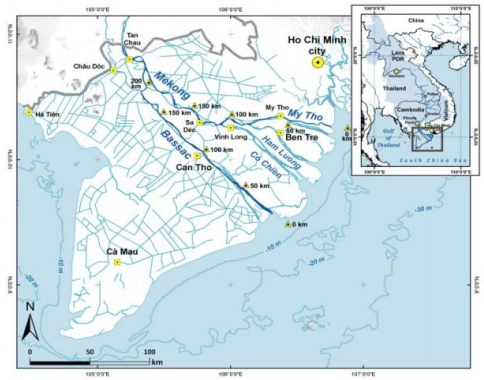

Figure 1. Coastal plain studied in lower Mekong Delta (Source: Website of University of Science)

Coastal mangroves, along with the Mekong's sea dykes, have the effect of preventing negative impacts from the sea on land (tide,wind, storm, saltwater, etc.), increasing sedimentation, and protecting the environment as well as coastal ecosystems.

With such an important role, however mangrove forests in the coastal lower Mekong Delta have been severely degraded. According to the report of the Directorate of Forestry at the 2016 summation meeting, it is estimated that in the five years from 2011 to 2016, the area of mangrove forest along the lower Mekong River has decreased by 15,339 ha (nearly 10%), from 194,723 hectares in 2011 to 179,384 hectares in 2016 [2].

Coastal erosion and mangrove forest degradation in the Mekong Delta have been, and will continue to cause great social-economic and environmental damage. Annually, many houses, gardens, facilities and hundreds of hectares of mangrove forest have been cleared by coastal erosion. Many of the sea dyke sections

have been ruptured, causing saltwater to penetrate deeply into the farming fields, resulting in great damage. The problem is, how to prevent shoreline erosion, mangrove degradation, and how to bring living conditions and the natural environment back to the status as they were in before.

For that reason, conducting research to identify the currentsituation, analyzing the causes, and on that basis, propose mitigation measures to step by step prevent erosion and restore mangrove forest area that was ruined is urgent.

II. Research methods and available data

To conduct a research to evaluate the current status, forecast trends, identify causes and propose appropriate and feasible solutions to prevent coastal erosion, coastal mangroves in the Mekong Delta, we have useda number of research methods:

- Synthesize, analyze historical sources, selectively inherit results from previous topics and projects related to this research content including the map of The Six Provinces of Southern Vietnammeasured by the French in 1861,1863, 1930, the measurement data of hydrological parameters, suspended sediment content at Tan Chau station, the documents of hydrological sediment at the Kratiestation of Mekong Commission, some of the measured data on Song Hau in Long Xuyen, Can Tho, Song Hau at the estuariesof Vam Nao, My Thuan.

- Process remote sensing from satellite images and GIS geographic information systems. The content that needs to be implemented is: (i) digitizing and converting UTM coordinates; (ii) using ENVI 4.0 software for image collage; (iii) Using ArcGIS software to process, overlay mapping, topography map, satellite images of different periods, based on that, then, analyzing shoreline variation and mangrove forest.

Table 1. Satellite images used to analyze the development of the coastal plain in Mekong Delta

TT	Time	Types of data	Format	Ratio/ Resolution
1	1965	Topography map	Vector	1/50.000
2	1989	Landsat TM	Raster	15m x 15m
3	2001	Landsat ETM	Raster	15m x 15m
4	2006	Landsat ETM	Raster	15m x 15m
5	2008	Landsat ETM	Raster	15m x 15m
6	2010	Landsat ETM	Raster	15m x 15m
7	2014	Landsat ETM	Raster	15m x 15m

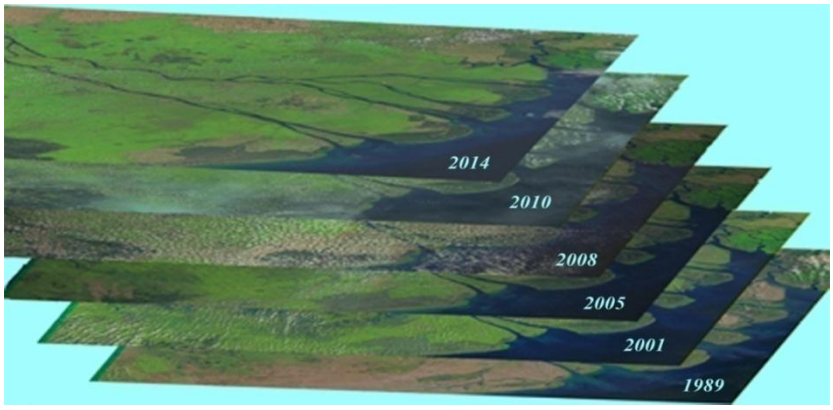

Figure 2. Map integration to determine the coastal erosion mechanism of the Mekong Delta

In addition, the field surveyed and interviewed local people to verify and evaluate the results obtained from satellite image analysis and map overlays.

-Apply numerical models, namelySWAT, Mike 11, Mike 21, Litprof, Litline ... to simulate the effects of waves, winds, storms, coastal currents, muddy areas, and the construction of upstream projectson the coastal zone, with the cases of climate change and sea level rise to varying degrees. Based on that, the causes and evolution of the coastline in space and time are determined. The study steps presented above are shown in Figure 3.

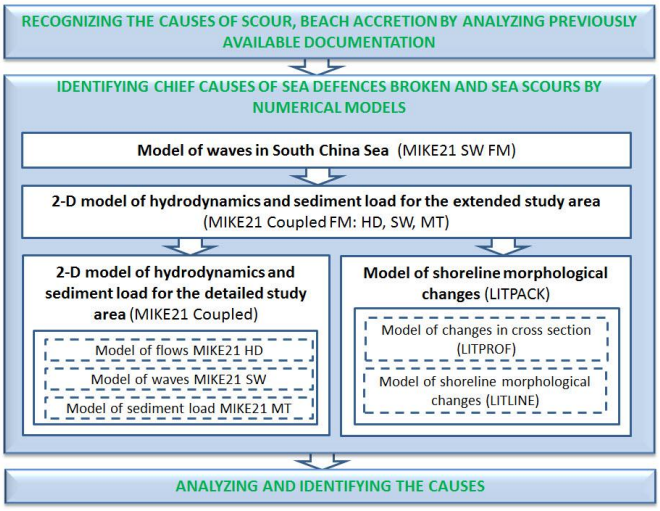

Figure 3. Diagram of research steps to determine the causes of coastal erosion inthe Mekong Delta - The scope of the study on the numerical model is shown in Figure 4, while the result of river evaluation and storm surge are shown in Figure 5.

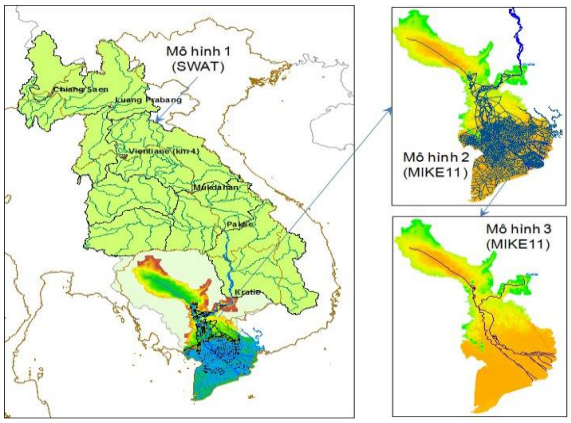

Figure 4. Models for calculating loadand distribution of sediment in the Mekong River

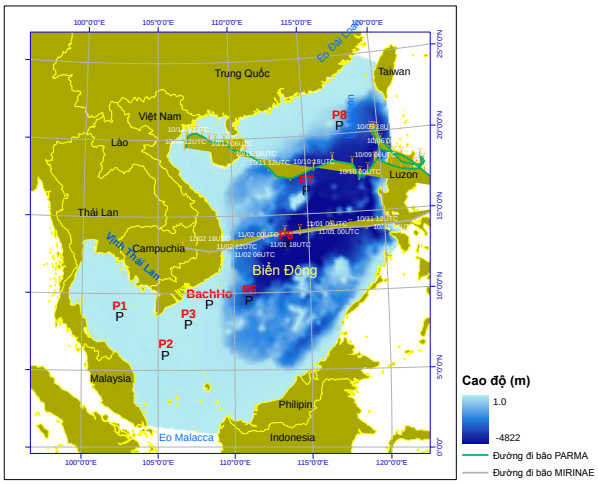

Figure 5. Experimental locations for wave and storm surge in the South China Sea

- Documentation of chain of hydropower plants on the Mekong mainstream and basic technical parameters are shown in Figure 6.

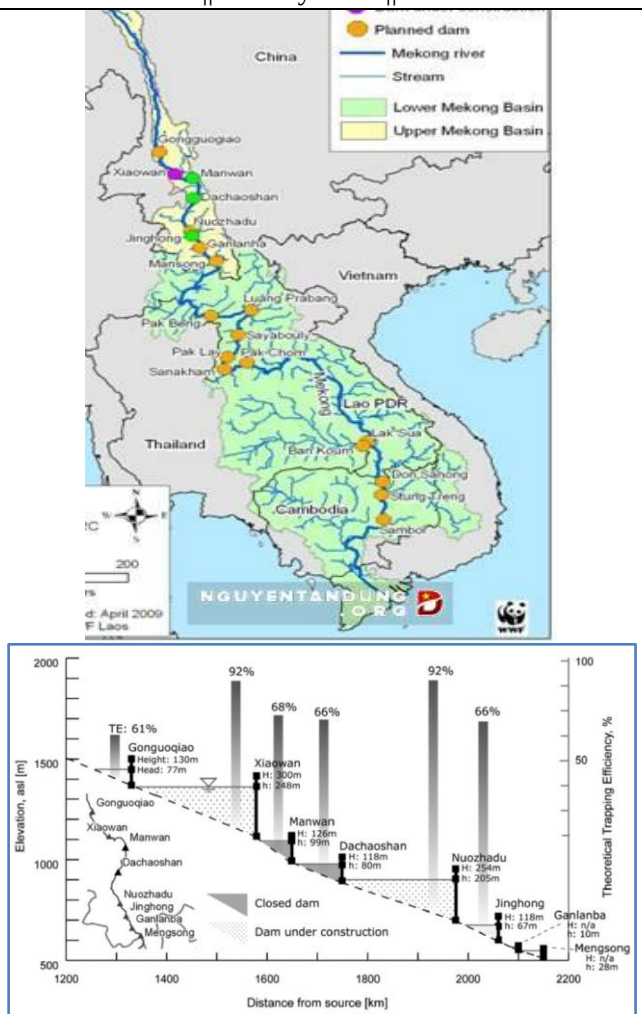

Figure 6. Chain of hydropower plants system on the Mekong mainstream (location, dam height, water column, and sedimentation factor). Source: Kummu and Varis[8]

- Research on the practical reality model (Scale1:1) is carried out for the purpose of examining the results obtained from numerical modeling, satellite image interpretation, remote sensing and data monitoring, measuring and evaluating the reaction of the dynamite regime in the study area as the results of nature changes and human exploitation. On that basis, the causes, mechanisms and forecasts of accurate future changes in erosion and the direction of feasible and appropriate solutions will be identified.

III. Results and discussion

III.1 The erosion and mangrove degradation of the coastal zoneinthe Mekong Delta

The overview of coastal erosion and mangrove degradation in the Mekong Delta is synthesized and shown in Figure 7. This results is established by numerical models, analysing remote sensing images, GIS satellite images, analyzing historical documents from different sources [3,4], then verifying reality.

Figure 7. Coastal erosion and mangrove degradation in the Mekong Delta

Some areas of rapid erosion such as Go Cong Dong (Tien Giang province), Vinh Chau (Soc Trang province), Ganh Hao (Bac Lieu province), Ca Mau (Ca Mau province) show that the smaller the width of the protective forest belt is, the faster the erosion occurs.


Figure 8. Coastal erosion and mangrove degradation in Go Cong, Tien Giang province


Figure 9. Coastal erosion and mangrove degradation in Vinh Chau, Soc Trang province

In recent years, the area of mangroves has lost about 500 ha. Of these, 24 areas are regularly eroded, with rates ranging from 5 to 45 m per year, of a total length of about 250 km. Details are shown in table 2.

Table 2. Number of coastal erosion sites by province

No.	Province	Scour			Erosion and sedimentation		Accretion		
		Sites	Length (km)	Speed min-max (m/yr)	Sites	Length (km)	Sites	Length (km)	Speed min-max (m/yr)
1	Tien Giang	1	17	10-15			1	16,49	
2	Ben Tre	1	8,51	10-15			4	88,568	0-10
3	Tra Vinh	4	24,44	5-30			2	41,86	30-60
4	Soc Trang	3	29,6	5-10			3	30,87	
5	Bac Lieu	2	15	10-20	1	18,64	1	22	
6	Ca Mau	12	150	5-40			2	70,75	15-80
7	Kien Giang	1	6,19	5-20	3	76,7	3	43,06	
	Total	**24**	**250,74**		**4**	**95,34**	**16**	**313,598**	

III.2 Causes of erosion and degradation of mangrove forests along the coastal zone of the Mekong Delta

The results of the study have identified a combination of causes of coastal erosion in the Mekong River, shown in Figure 10. There are two groups of subjective and objective causes, group one is human impacts and other is natural impacts.

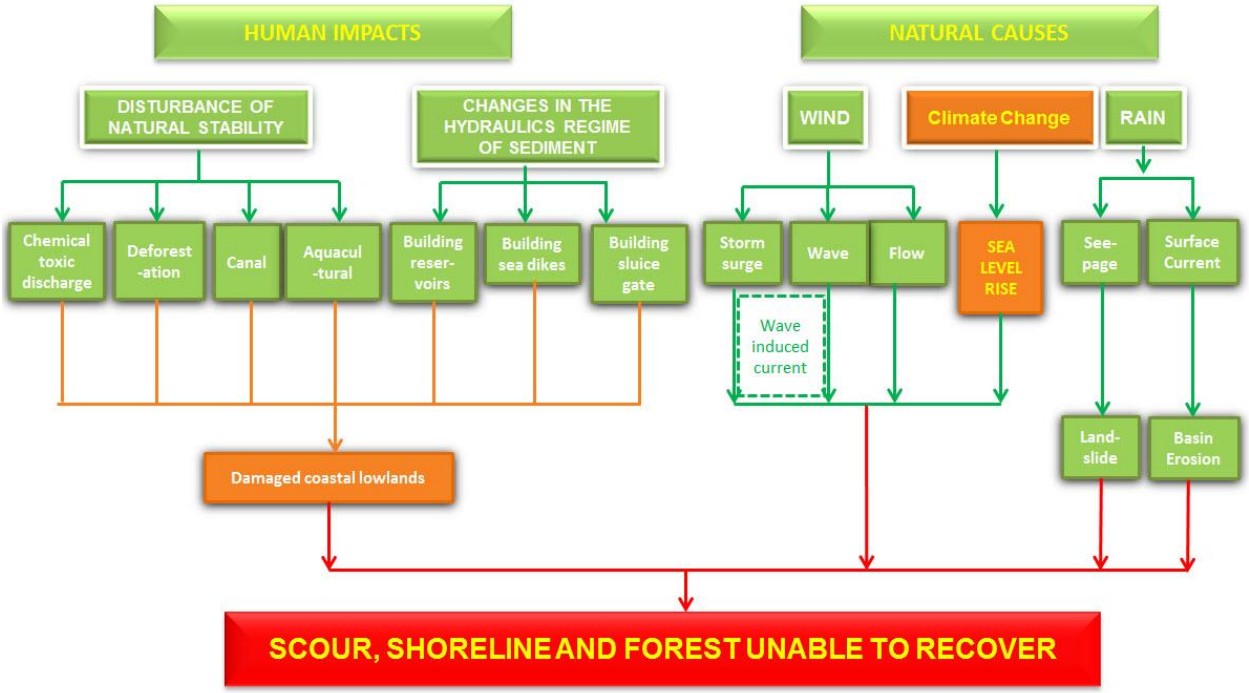

Figure 10. Combination of causes of erosion along the Mekong River

- Subjective causes include:

+ Group of human activities disrupts the completeness, natural state of long-term stability of the coast, mangrove forests such as spreading toxic chemicals during the war.

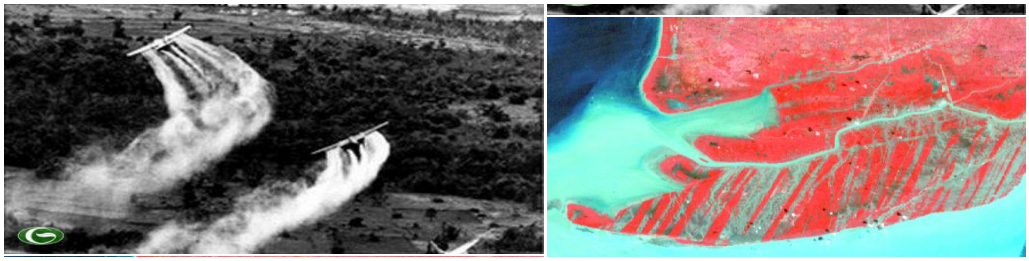

Figure 11. Toxic chemicals discharge to destroy submerged forests of Ca Mau province

Deforestation, digging canals for flood drainage, alum alkalis and aquaculture.

Figure 12. Digging of canals and ponds ... broke the natural stability of the coastal lowlands

Digging canals, laying drains, building sea dykes, encroaching sea and narrowing river estuary that causedamages to coastal area.

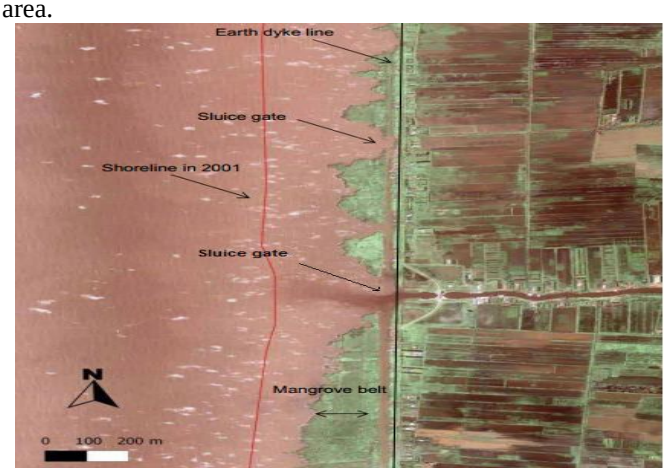

Figure 13. Canal digging, culvert and sea dyke construction causing damage to the coastal zone [14]

Figure 14. Ganh Hao beach and estuarine encroachment has changed the morphology andcaused severe erosion for many years. [7]

+ Groups of human activities change the dynamics, sediment deficiency, and nutrition. The results show that hydropower reservoirs on the Mekong mainstream retained a significant amount of sediment, reducing the amount of silt to the sea by more than 40% [5,6]. Construction of sea dykes prevents the overflows of nutrition from the beach, mangrove forests and non-regenerable forest belts, as shown in Figure 15.

Figure 15. The beach lacks alluvium and nutrition and is always affected by waves and currents, so trees cannot grow. (Photo taken 6/2017)

- Group of objective causes (natural factors):

The group of causes consists of a number of factors, but can be divided into two categories: active elements and passive elements. Active elements break the morphology of natural stability and gradually expand erosion in space and time such as wind, tide ..., while passive elements belong to the group of integers. The objective factor, which is the property of the coastal zone such as: shoreline material, shoreline morphology, coastal terrain, vegetation cover, has a great impact on the scale and speed of erosion. Climate change and sea level rise have deepened the situation of coastal erosion and mangrove forest degradation in the Mekong Delta, due to the more intensified, more powerful, and deeper coastal areasas well asstronger pressure . Below is a photo of the coastal protection work in the populated area of Ganh Hao town, Bac Lieu province. Sheet piles is builtover 10 years (builtin 2005),and it was broken in 4/2017.

Figure 16. The protection of Ganh Hao town in Bac Lieu province broken by waves in 4/2017 (source: tuoitre.vn)

III.3 Orientation of solutionsto prevent erosion and mangrove degradation in the coastal zonein the Mekong Delta

After careful analyzing and evaluating the types of solutions that have been implemented in many countries around the world, we would like to synthesize the logic diagrams presented below.

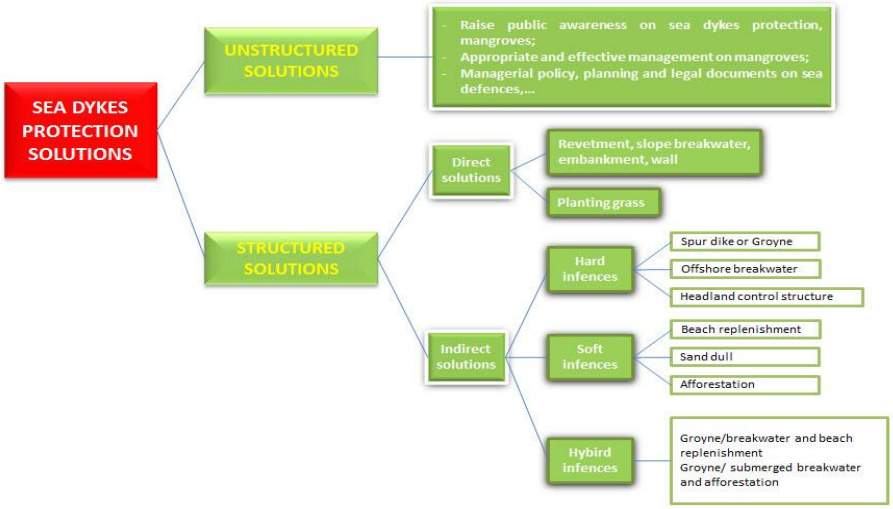

Figure 17. Synthesis of mitigated measuredforerosion and mangrove degradation of the coastal zonein the Mekong Delta.

There are two main groups of solutions that arenon-structureand the structure solutions. Among these, each hybrid solution group is divided into different measures, suitable to specific conditions (characteristics of erosion, causes, mechanisms, geological and wave conditions) of each area.

Through monitoring, studying the process of forming and extending erosion, as well as mangrove degradation, simulating results of wind, waves, currents and coastal sediments along with concluding practical experience from a series of solutions having been implemented along the coastal lowland in the lower Mekong, the author would like to share and exchange:

-Implementation of non-structure on management of the coastal zone, estuaries ... to avoid the occurrence of vulnerability, loss of natural stability of coastal lowlands and mangrove forests will achieve great effects.

-Direct protection engineering solutions should only be implemented to protect urban areas and residential areas which are directly impacted by sea waves;

-Application of Geotube to build longshore reef breakwatersdoes not bring about the desired effect, because the peak is not preserved, often torn by marine creatures after a short time;

Figure 18. Wave collection by Geotube at Nha Mat in Bac Lieu province has no effect on wave deceleration due to the crest has been lower than the 1.2 m design.

-Beach replenishment by bamboo and melaleuca forest fences, step by step rehabilitating the mangroves at bend scourin shallow sea then moving to deeper positions. Experience from the GIZ project shows that mangroves are rapidly and sustainably rehabilitated. Below is a fence to faciliate the process of accretion in the Bac Lieu coastal area, with the re-depositing speed within the fence of about 10 cm per year [13].

Figure 19. The fencefor beach feeding and rehabilitating mangrove forests in the GIZ project in Bac Lieu,

When silt reaches a height of more than 10 cm, the plants will grow on their own and are very stable in the long run regardless of the effects of natural conditions, waves and winds. Survival rate after one year is over 90%, while the survival rate of trees which are brought from nursery gardens to be planted in this area is only 10%.

Figure 20. Rhizophora regeneration when sediment layer is over 10 cm at Soc Trang beach (photo taken 6/2017).

IV. Conclusions and recommendations

Based on the survey, data measured by the authors and concurrently collected from the annual reports of localities, from the previous related projects we have conducted, we analysed, evaluated and simulated on 1D and 2D numerical models of the impact of upstream projects, sand exploitation at some locations along the Mekong River to hydrological regime, sedimentation along the lower Mekong River under the conditions of climate change and sea water rise under forecasted scenarios (low, medium and high) up to 2100. The result is a map of coastal mangrove erosion and degradation in the lower Mekong River, shown in Figure 8. We scientificallysynthesized and analyzed the causes and solutions to erosion and degradation for mangrove forestsin the study area.

This study recommends that a T-fence for accretion and rehabilitation of mangroves at shoreline sites which have been heavily encroached on the shore be built. In further studies, detailed wave parameters, coastal currents, sediment load at each location to arrange fences with suitable height, direction will be carefully examined.

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