EXISTING SHORELINE, SEA DYKE, AND SHORE PROTECTION WORKS IN THE LOWER MEKONG DELTA, VIETNAM AND ORIENTED SOLUTIONS FOR STABILITY

Dinh Cong San[1], Tang Duc Thang[2], Le Manh Hung[1]

[1] Center for River training and Natural disaster Mitigation, Southern Institute of Water Resources Research (SIWRR), E-mail:dinhcongsan61@gmail.com, manhhungvawr@gmail.com
[2] Vietnam Academy for Water Resources, E-mail: tdthang.siwrr@gmail.com

ABSTRACT

The coastal area of the Lower Mekong Delta (LMD) is influenced by waves, tidal currents, changing sediment loads from the Mekong, and Sai Gon-Dong Nai rivers, and storm surges from the East and West Sea. In addition, human activity has an impact on erosion and deposition processes through dyke construction and drainage, agriculture, aquaculture, and fishery exploitation along the coastal areas. In recent years, the impact of upstream dams, especially on the Mekong main river, has reduced sediment feeding into the LMD and its estuary. All of these impacts have caused shore erosion along approximately two thirds of the total coastline length, and a land loss rate of about 500 ha/year in the past ten years. In the future, climate change and sea level rise will make this situation worse. In order to prepare a national research program dealing with this issue, this paper presents the existing situation concerning the shoreline, sea dyke, and shore protection works in the area and an oriented solution for the stability of the LMD coast in Vietnam.

Keywords: Shore erosion, Shore protection works, LMD

1 INTRODUCTION

The low elevation coastal zone in the world by the year 2000 occupied 2% area and home of 600 million people in which eight of top ten largest city situated. Coastal regions and populations are exposed to natural hazards and faced with unsustainable practices. Most of the coastal areas of mega deltas are under the threat of accelerated subsidence and erosion due to lacking of sediment from upstream, inappropriate land use, climate change and sea level rise etc (Anthony et al. (2015), Ramesh, R et al (2016), Toan et al. (2016), Liviu Giosan (2014)). The Lower Mekong Delta (LMD) is one of these deltas.

The Lower Mekong Delta (LMD) covers 13 provinces and cities in the South of Vietnam (Fig. 1) namely: Long An, Tien Giang, Ben Tre, Dong Thap, Vinh Long, Tra Vinh, Soc Trang, An Giang, Kien Giang, Hau Giang, Bac Lieu, and Ca Mau and Can Tho. The total area of the LMD is 3.95×10^6 ha, accounting for 12% of the country, with a population of 19 millions (21% of the national population) (Hung et al. (2013)). Anthony et al. (2015) showed that the LMD provides 50%, 90%, and 60% of Vietnam's food, rice production (the world's second most important rice exporter), and seafood, respectively. The delta is also a very active area for agriculture and animal husbandry, it has the most concentrated fish biodiversity per unit area of any large river basin in the world and is ranked second only to the Amazon in overall biodiversity.

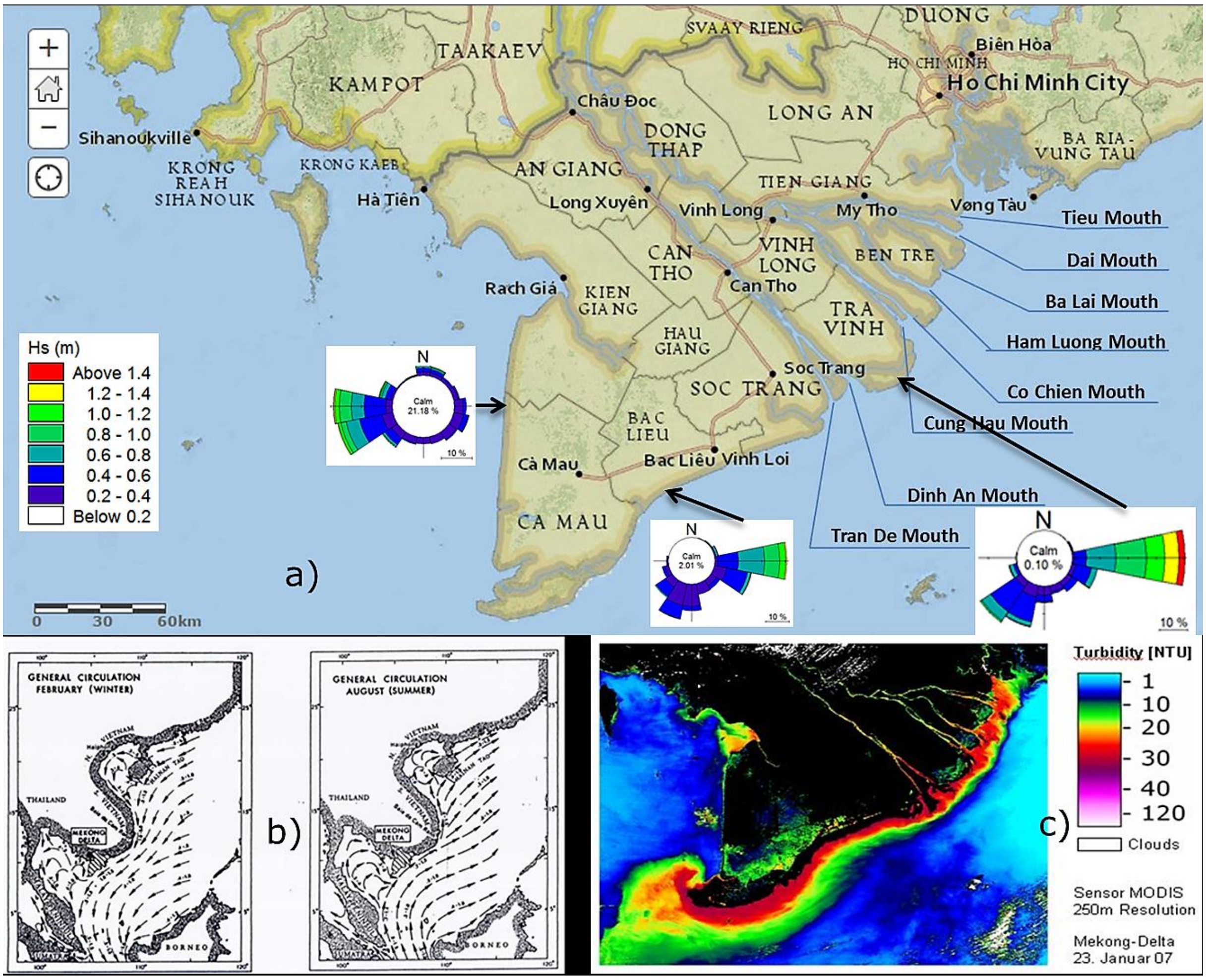

Figure1. Map of Vietnamese Lower Mekong Delta and near shore wave roses (a), wind directions in winter (b-left) and summer (b-right), and sediment concentration (turbidity) in winter (c)[1]

However, the LMD is impacted by the development of the Upper Mekong countries and also by influences from the East Sea. In the context of climate change, sea level rise and especially the development of upstream countries, the risk of floods, drought, salinity intrusion, erosion and deposition in the rivers, canals and coastal areas of the LMD are great challenges.

This paper discusses the existing shoreline, related impacts on sea dyke and shore protection works, and presents an oriented solution for the stability of the LMD coastal area.

2 METHODOLOGY

The erosion, deposition, mangrove forest belts variation of coastal areas in the LMD were reviewed and synthesized from previous projects of Chuong et al. (2008) and Tuan et al. (2004) where satellite images with GIS method combined with field observations (by GPS) were used to estimate erosion and deposition rates. The mangrove forest belts and erosion/deposition rate have been recently updated (2016) thank to Google earth toolbar where historical imagery and time slider are used to move between acquisition dates. Most of available high resolution (1 meter) of Landsat images are used

[1] a) Map of Vietnamese Lower Mekong Delta and nearshore wave roses (Source:
b) Winter and Summer ocean currents on the East Coast. Arrows denote the average flow direction, the figures indicate the average flow rate in units kn (1 kn ≈ 0:51 m / s) (Source: U.S. Naval Occeanographic Office, 1957)
c) Distribution coastal turbidity in the Lower Mekong Delta during the NorthEast monsoon (1/2007) built from MODIS satellite image analysis (Source: EOMAP)

(from 2000 to 2016). In addition, landmarks (such as houses, buildings) are also used to correct the erosion/deposition rate results.

Sea dyke and shore protection works in the LMD are also field examined. The pros and cons of them have been observed and examined from field survey as well as referred to related literatures. Then the oriented solutions are proposed based on lessons learned from protection measures.

3 RESULTS

3.1 Existing and shoreline variation

The coastal-strip length from the Ho Chi Minh City to Kien Giang is about 774 km. The variation trends show constantly increasing erosion and reducing deposition, causing damage to mangrove forests, land loss and threats to sea dyke systems - the final defenses that protect inland production areas in the Delta from waves, storms surges, etc. Figure 2 expresses the recent rates in m/year of erosion (red color), deposition (blue color) and alternative erosion and deposition (dash green color) which were synthesized from previous projects of Chuong et al. (2008) and Tuan et al. (2004) and updated by Google earth maps overlaid in 2016.

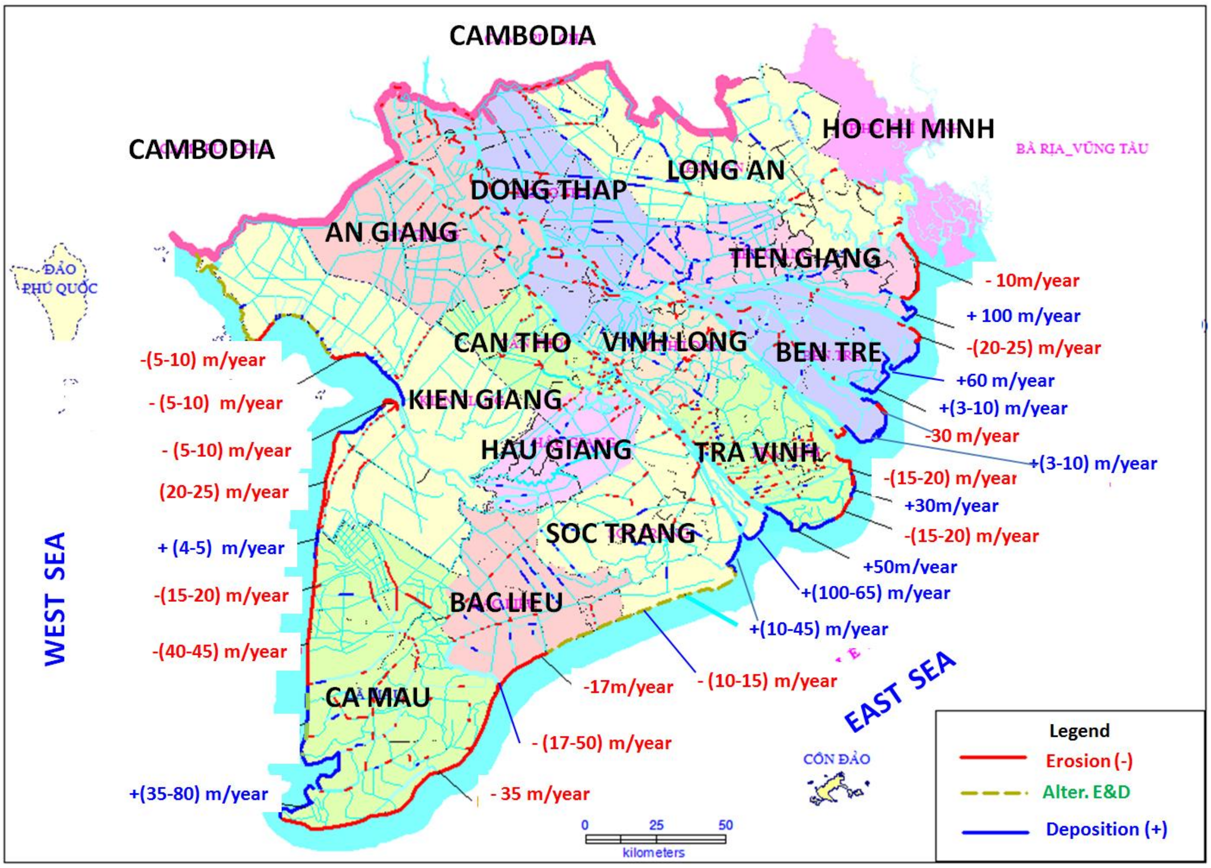

Figure 2.Existing erosion and deposition situation along the coastline of LMD

3.1.1 Tien Giang province

In recent years, the 17 km key sea dyke at Go Cong Dong district, mangrove forests have been gradually destroyed with increasing rate, up to 10 m/year. There is only about 1.5 km of coastline which has been accreted about 10-15 m/year. The coast between the Tieu and Dai river mouths experienced very strong accretion with an average rate of 100 m/year.

3.1.2 Ben Tre province

The coastline of the Ba Tri and Binh Dai districts has not eroded, except for the Dai river mouth, which has a maximum erosion rate of 25 m/year whereas the Ba Lai river mouth has strongest deposition rate of 60 m/year. From the Ham Luong to Co Chien River mouths, deposition prevails. From 1989 to date, alternative erosion and deposition have taken place. From the Ham Luong river mouth southward 7 km the erosion rate has been about 30 m/year. From that point to Co Chien river mouth, the deposition rate has been about 60 m/year.

3.1.3 Tra Vinh province

In 50 km coastline, a part of 25 km from the Cung Hau river mouth to Dan Thanh hamlet has an erosion rate of 15-20 m/year whereas from Dan Thanh hamlet to the Dinh An river mouth has generally been deposited with the largest rate of 50 m/year to date.

3.1.4 Soc Trang province

The 12 km long of Cu Lao Dung coastline has been deposited with the rate over 100 m/year from 1965 to 1989 and then reduced to 65 m/year up to date. The 8 km from the Tran De to the My Thanh river mouth, from 1965 to 1989 deposition rate was 10-15 m/year and 20-40 m/year to date. From the My Thanh river mouth to Bac Lieu province, about 52 km length of the Vinh Chau district, erosion and deposition have alternated. From 1989 to 2001, from Vinh Chau town to Bac Lieu province erosion occurred at a rate of about 10 m/year. The current erosion rate is about 15 m/year. At a location near Bac Lieu province, erosion has extended into the base of the sea dyke.

3.1.5 Bac Lieu province

With the coastline length of 56 km, from 1965 to 2008 there was seaward deposition, except 6 km near Soc Trang province and 9 km near the Ganh Hao river mouth, where erosion rate was 10 m/year. During the period 1965-1989 the Ganh Hao river mouth erosion rate was 17 m/year and then up to 50 m/year over the period 1989 – 2001 before it was protected by a revetment.

3.1.6 Ca Mau province

From 1965 to date the 100 km East Sea coastal section has eroded at a rate of 35 m/year causing an area more than 1.5 km width lost to the sea. The 154 km long the West Sea coast experienced alternating erosion and deposition in previous years but increasing erosion rate recently. The largest deposition rate occurred at Ca Mau Cape. From 1965 to 2001, an area approximately 3 km width expanded seaward at an average rate of about 80 m/year. From 2001 to date, the deposition rate has reduced to 35 m/year at the Cape.

3.1.7 Kien Giang province

Being influenced by the West Sea and the Gulf of Thailand, this coastal strip is quite stable and deposition is the main occurrence in the past. From 1965 to 2008 deposition occurred at a rate of 5-10 m/year at the An Bien and An Minh district border and expanded by about 2 km at a rate of 50 m/year. However, in recent years erosion has occurred and threatened the safety of sea dykes in some local areas at An Minh - An Bien, Mui Ranh, and Vam Ray. The maximum erosion rate reaches to 45 m/year to date.

3.2 Existing sea dyke and mangrove forest belt

Sea dyke system in the LMD had been developed for few decades. The dykes were, on average, 2 m of height, 6 m of width, with seaward slope of 1:3 and shoreward slope of 1:2. Most of slope protection were grass cover.

Total length of sea dykes in the LMD is about 630 km (Fig. 3). Sea dykes were built on soft/weak soil with a small loading and slow consolidation capacity. Sea dykes were made of in-situ soil and protected by the mangrove forest seaward.

The LMD has a mangrove forest area of about 51,000 ha. Because erosion and human activities e.g. cutting forest for aquaculture and inshore fishing, the loss of coastal mangroves is around 500 ha/year (about 1%). Currently, many coastal parts of Bac Lieu, Ca Mau and Kien Giang have no mangrove forest belt seaward of the sea dykes. The largest mangrove forest belt width in the LMD is less than 1 km.

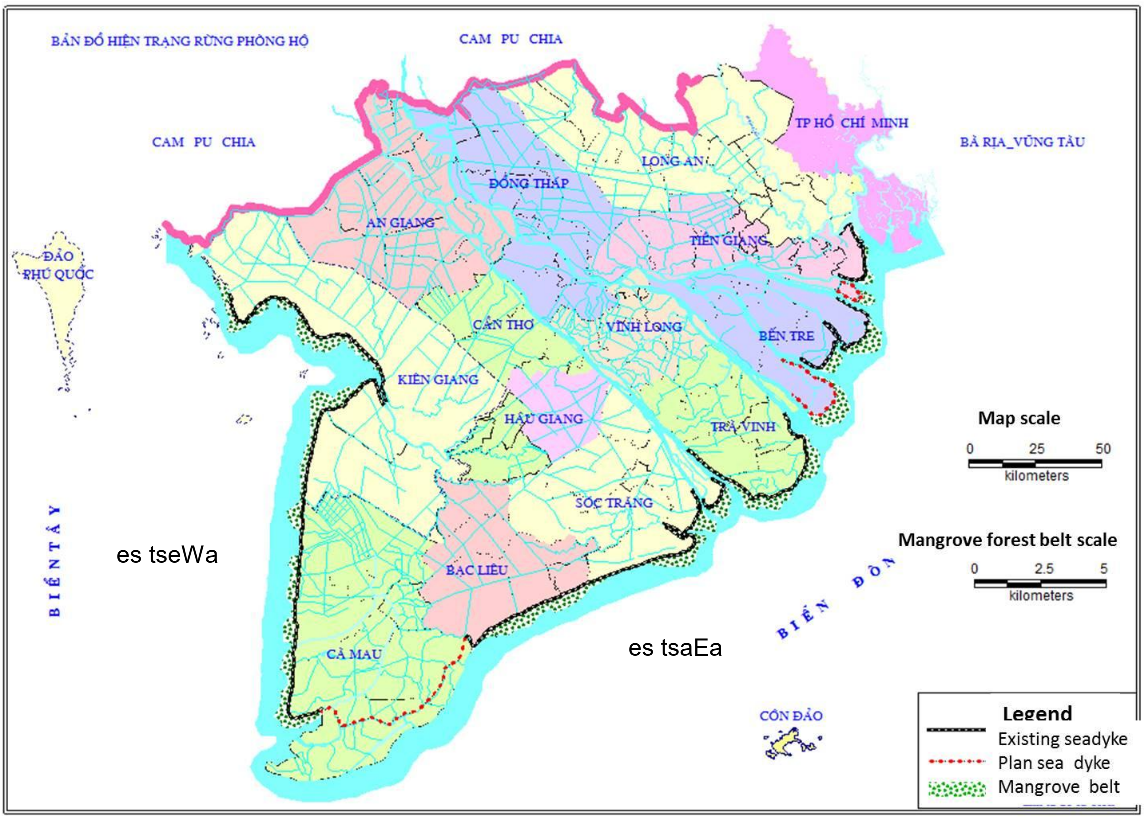

Figure 3.Existing sea dykes and mangrove forest belt in the LMD

3.3 Existing shore protection works

Over the years, some types of shore protection works have been built along the LMD coastline (Table 1). These are i) shore/dyke protective embankments (K) with concrete walls, concrete blocks, ripraps or gabions and ii) breakwaters (G) with concrete piles (G1), riprap (G2), geotextile bags (Geotube - G3) (Fig. 4) and recently "soft" breakwater (G4) with local material fences (bamboo/ melaleuca piles) and filled with tree bunches in Soc Trang, Bac Lieu and Kien Giang by GIZ projects (Fig. 5). This "soft" structure is designed for wave and current attenuation so as to stimulate deposition and restore the mangrove forest.

In general, the total investment in shore protection works to prevent erosion in the LMD have been quite low, about VNĐ 1,513.4 billion, equivalent to USD 66.3 million to date (Table 1).

Table1.Types of coastal protection works in the LMD

Province	Shore protection works' name	Length (m)	Type	Unit price mil.VNĐ/m)	Cost (bil. VNĐ)
Tien Giang	Go Cong GC1(K.1) Revetment	3000	Concrete block	50	150
	Go Cong -GC2(K.1) Revetment	500	Concrete block	50	25
	Go Cong -GC3(K.1) Revetment	1500	Concrete block	50	75
Tra Vinh	Hiep Thanh -HT(K.1) Revetment	1325	Concrete block	90	119
	Con Trung -CT(K.1) Revetment	750	Concrete block	70	53

Province	Shore protection works' name	Length (m)	Type	Unit price mil.VNĐ/m)	Cost (bil. VNĐ)
Soc Trang	Vinh Chau -VC1(K.1) Revetment	380	Gabion	20	8
	Vinh Chau -VC2(K.1) Revetment	100	Gabion	20	2
	Vinh Chau -VC3 (K.1) Revetment	100	Gabion	20	2
	Mangrove rehabilitation GIZ (G4)	600	Bamboo fence	1.2	1
Bac Lieu	Nha Mat -NM1(K.1) Revetment	617	Concrete block	90	56
	Nha Mat -NM2(K.1) Revetment	522	Concrete block	90	47
	Geotube Breakwater at Nha Mat	1056	Geotube	5	5
	Mangrove rehabilitation -GIZ (G4)	2400	Bamboo fence	1.2	3
	Ganh Hao -GH(K.1) Revetment	3432	Concrete block	90	309
Ca Mau	Break water -GH(G1)	509	Concrete pile	40	20
	Break water -at Ca Mau cape - DM(G1)	2571	Concrete pile	40	103
	Khanh Hoi –KH (K) Revetment	1186	Plastic sheet, gabion	15	18
	Bien Tay -BT(K) Revetment	500	Concrete block	40	20
	Break water -BT(G1)	300	Concrete pile	40	12
	Break water Huong Mai-HM(G1)	6990	Concrete pile	40	280
Kien Giang	Mangrove rehabilitation KG-HĐ1 (G.4)	3500	Melaleuca fence	1.2	4
	Mangrove rehabilitation KG-HĐ2 (G.4)	300	Melaleuca fence	1.2	0
	Mangrove rehabilitation KG-HT (G.4)	100	Melaleuca fence	1.2	0
	Vam Ray (K) Revetment	300	Concrete block	40	12
Total					1,513.4

Figure 4.Breakwater by riprap (G2- Can Gio), geotube (G3- Bac Lieu), and concrete piles (G1- Ca Mau)

Figure 5.Wave and current attenuation fences at Soc Trang and Bac Lieu provinces by GIZ projects

4 DISCUSSIONS

4.1 Impacts on erosion and deposition in the LMD

Erosion and deposition are diverse and complex processes. Under the impacts of human activities, climate change, sea level rise conditions, erosion and deposition becomes more unpredictable.

For many deltas in the world, coastal erosion and subsidence are big challenge. Liviu Giosan et al. (2016) indicated the issues of lacking of sediment in medium and large deltas. Sediment reduction after their first dammed were 60%, 69%, 85%, 94%, 98% for Danbube, Mississippi, Rhône, Indus and Nile respectively. Moreover, subsidence rates in the deltas increased by human activities such as intense ground water use in Chao Phraya Delta in Thailand led to sinking by 5–15 centimeters/year or methane extraction in Po delta in Italy led to subside by 3–5 meters in the twentieth century.

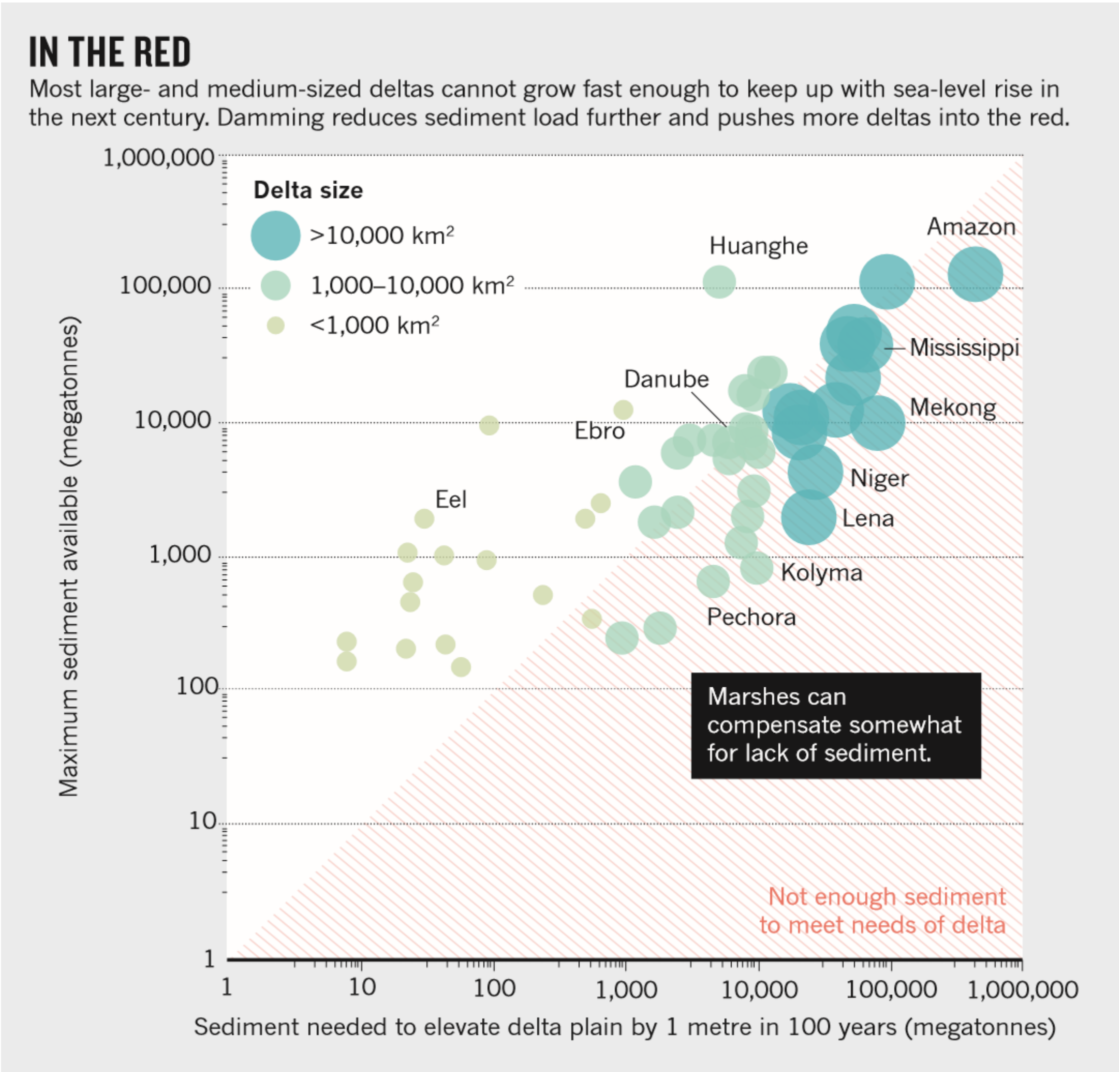

Figure 6. Issue of lacking sediment in the medium and large deltas in the world (after Liviu Giosan 2014)

The LMD coastal erosion and subsidence threats are a consequence the interaction between sediment sources, waves, tides, storm surges, soil structures and shore topography.

For sediment sources, due to human activities upstream countries especially hydropower dams in China, Laos in the past 20 years and Cambodia in the near future, sediment feeding the LMD reduced significantly. Le Manh Hung (2013) using SWAT model for the whole Mekong Delta in a national research project showed that with the scenario of 8 dams in China and Xayaburi dam in Laos operating, the reduction of sediment to the LMD (average 2007-2011) is 68% (52 million tons) compared to the baseline scenario (two dams Manwan and Dachaosan in China operating – 162 million tons). In the future, when Cambodia builds Sambo dam, the total sediment to the LMD are only 36.5 million tons (reduced 77.5% compared to the baseline.

For soil structure impact, except for the Ha Tien area, most of the coastal and estuary areas in LMD are comprised of alluvial sediment, mostly are fine sand, silt and clay or mixed, which is very sensitive to erosion by waves and currents.

For the shoreline direction impact, because the shoreline of East Sea areas is normal to the East or Northeast monsoon direction, the two main wind directions in the Delta, many locations are facing rapid erosion, namely: Go Cong, the south bank of the Dai river mouth, and the Ham Luong and Cung Hau river mouths, except for segments located in the northern part of the Mekong estuaries. The West Sea shoreline experiences strong erosion due to being normal to the West or Southwest monsoon directions. In contrast, the Bay Hap River mouth and Rach Gia Gulf regions, which are protected from the Southwest monsoon, tend to be deposited.

The impacts of wind, waves and currents are significant important. Waves are usually generated by the wind. During wave action processes, surf and waves pounding the shore cause pressures, which excavate and abrade the seabed and shore structures, causing erosion and transporting sediment to other areas by current. As presented in Figure 1, both of the East and West sea parts, the dominant wave directions are nearly normal to the shoreline, and the net current of the climate year (subtract the Winter and Summer currents) which had the southwest direction caused the sediment transported to southwest of the Delta and deposited at Ca Mau cape.

Mangrove forest belt is very necessary to protect sea dyke or to reduce dyke height (Albers et al. (2015), Albers et al. (2013)). High waves can cause the destruction of exposed infrastructures, such as sea dykes along the coast. Mazda Y at al. (2007) pointed out that a wave of 1.0 m in height was reduced to a height of 5 cm at the dyke's toe after passing through a 5 year old mangrove forest belt of 1.5 km wide. Without the presence of a mangrove forest, the wave height reduces to 75 cm, this due only to bottom friction. In addition, the ecosystem services provided by mangroves also have implications for food security and incomes due to their biodiversity. In fact, the less the mangrove forest belt width, the more serious the erosion process in the LMD.

For human activity impacts, over exploitation in the LMD, especially deforestation to convert mangrove forest to aquaculture land (such as shrimp ponds) and fisheries by local people, has in recent decades severely degraded. Aquaculture, combined with irrigation and drainage systems and the sea dyke system have also changed the coastal environment, causing degradation of mangroves. The construction of dams on the Mekong River and Sai Gon–Dong Nai river systems have significantly reduced sediment loads downstream which, causing coastal erosion (Anthony et al. (2015), (Lu et al. (2006), (Toan (2014)). In addition, over sand mining in the Mekong and Bassac rivers (Hung et al. (2013)) as well as ground water extraction have caused river bank erosion and land subsidence of the order of 1.9 to 2.8 cm/year in Ca Mau province (NGI (2012)) and could also be the causes of coastal erosion.

4.2 Shore protection work evaluation and oriented solutions in the LMD

Shore protection measures from around the world have been modified and applied in the LMD. These were revetments, breakwaters/groynes including local material fences.

To date, the dyke revetments have been built mostly in the area without mangrove forest belt (Figure 6) and considered to be successful in the short term due to it can't stop erosion at foreshore such as in Go Cong district. Moreover, the existing dykeline systems which have been built for decades and the plan ones seem to be vulnerable due to the increasing adverse impacts from the LMD upstream as well as from the sea. Retreat for an appropriate distance is an option and in general for the dyke line/route due to the future context. In general technical, socio-economic and environmental aspects should be considered.

Breakwaters were rarely used in LMD (Table 1) and there have been no submerge one. Three types were applied using local bamboo/melaleuca fences, concrete pile wall and geotube. Field investigation showed that the local material fences were successful for mangrove rehabilitation in one place (at Soc

Trang) but the other (at Bac Lieu) (Albers et al. (2015)) and therefore needed to define the applicable conditions of foreshore (such as ranges of elevation, soil properties, sediment, current and wave height limits). Moreover, such local materials are rapidly degraded due to site environment associated with wave attack. The geotube breakwater have failed due to poor design and needed to be improved. The concrete pile breakwater (Fig. 4) could trap sediment but it were “too hard” for environment and costly.

Therefore, the oriented structural measures for shore protection should be combined soundly dyke revetments, local material fences in the middle and breakwaters for wave and current attenuation (Fig. 7). The breakwater can be non-submerge or submerge one. Thank to “hard” breakwater, local material fences can be survived longer to trap fine sediment for mangrove rehabilitation. The scale of these structures obviously are depended on the site-specific conditions of wave, current, sediment, ecologic etc..

As discussed above, the mangrove forest belt is crucial important for shore protection. To protect this belt from anthropogenic impacts, one of the non-structural measures is mangrove management such as co-management model (Albers et al. (2015)) in Au Tho B village (Soc Trang province) which should be encouraged and scaled up for sustainable and effective mangrove protection.

Due to shore protection works were carried out only when serious erosion occurred, data of wind, wave, current and especially sediment are needed but they are always lacking because there are only three offshore wave gauging stations (Vung Tau, Bach Ho and Con Dao) in the LMD region. There are no near shore gauging stations but only in-situ and scattering data serving the specific project purposes. In addition, sediment loads from upstream to the LMD are uncertain due to limited measurement (Anthony et al. (2015)). Therefore, in the long term, there should have integrated plans for LMD coastal stabilization. The plans should focus on, firstly to monitor frequently and seasonally hydrodynamics (wave, tide, current) and sediment factors for typical areas (such as estuary in the East sea, non-estuary East and West sea) and sediment load from upstream for study and design purposes. With very long erosion shoreline with land loss of 500 ha/year (Anthony et al. (2015)), structural measures are infeasible due to financial constraint therefore the plans secondly are to study and predict erosion and deposition trends under the recent and future impact conditions so as to focus on “cheap measures” as mangrove rehabilitation (Albers et al. (2013)) and to protect the high population and infrastructure density areas.

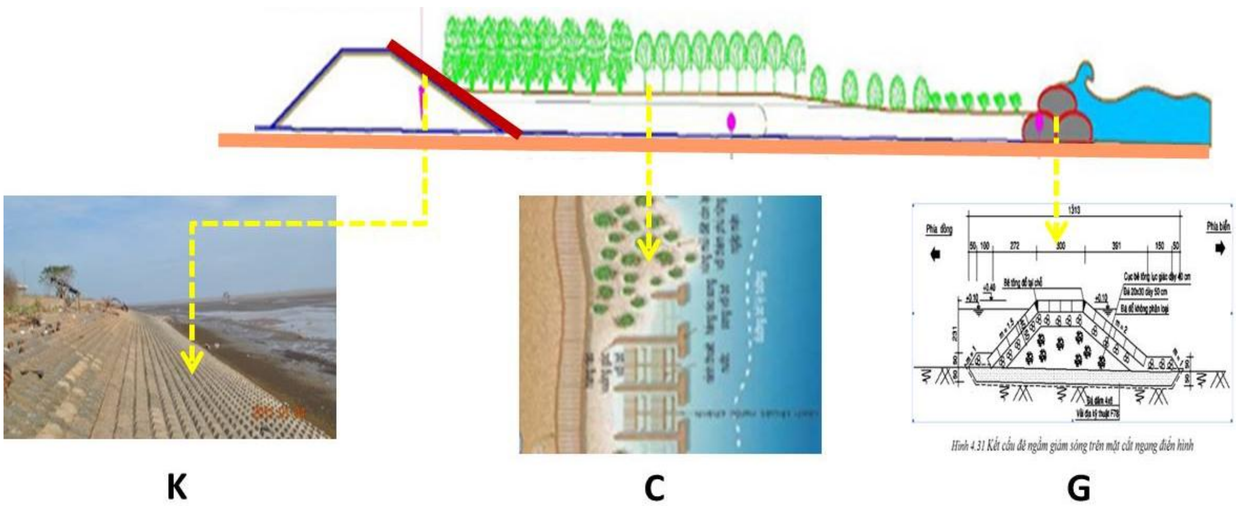

Figure 7.Oriented solutions of shore protection in the LMD

5 CONCLUSION AND RECOMENDATION

Like many large and medium deltas in the world, the LMD has been facing up to shore erosion due to lacking of sediment feeding (damming upstream), inappropriate anthropogenic activities such as intense ground water extraction, sand mining in the Lower Mekong River, over-exploitation in agriculture etc.. In addition, climate change and sea level rise have exacerbated the situation. As the results, about 500 ha/year of land and mangrove forest lost up to date.

To mitigate shore erosion, local and central governments have built many types of seadyke and shore protection works in the LMD. However, due to lacking of field data and integrated studies, protection measures were not always successful in both short and long terms. Non-structural measures (such as mangrove forest management) were limitedly applied.

Therefore, to protect the LMD coastal areas from erosion, there should have general plans for coastal stabilization, focusing on firstly to monitor natural data frequently (wave, current, sediment etc.), secondly to predict erosion and deposition trends under the recent and future impact conditions (including human, climate change and sea water level rise impacts) and thirdly to study the sound protection structures and non-structures. For the structural measures the combined soundly dyke revetments and local material fences in the middle to trap sediment and breakwaters for wave and current attenuation offshore need to study for the whole LMD region (large scale) and then in detail for each protection area (local scale). In general, the mangrove forest belt rehabilitation should be prioritized and mangrove management such as co-management model is needed to enhance sustainable shore protection.

6 ACKNOWLEDGMENTS

This work was partially supported by JSPS Core-to-Core Program B. Asia-Africa Science Platforms. We also wish to thank Dr Yamanaka Rieko and Dr. Oliver Saavedra at Tokyo institute of Technology for their supports.

REFERENCES

Albers T. & Schmitt K. (2015) Dyke design, floodplain restoration and mangrove co-management as parts of an area coastal protection strategy for the mud coasts of the Mekong Delta, Vietnam. *Wetlands Ecol Manage* (2015) 23:991–1004. DOI 10.1007/s11273-015-9441-3.

Albers T, Schmitt K, Pham TT, Dinh CS. (2013) Site-specific and integrated adaptation to climate change in the coastal mangrove zone of Soc Trang Province, Viet Nam. *J Coast Conserv* (2013) 17:545–558. DOI 10.1007/s11852-013-0253-4.

Edward JA, Guillaume B, Manon B, Marc G, Philippe D, Nguyen VL (2015) Linking rapid erosion of the Mekong River delta to human activities. *Scientific Reports 5*:14745. DOI:10.1038/srep14745.

Mazda Y, Magi M, Kogo M, PN Hong (1997) Mangroves as a coastal protection from waves in the Tong King Delta, Vietnam. *Mangroves and salt marshes 1*:127-135. DOI:10.1023/A:1009928003700.

Le Manh Hung (2013) Research the effects of sand mining activities to channel morphology of Cuu Long River (Mekong and Bassac Rivers) and suggest solution on appropriate plan and management. National research project (MOST), *Final Report - SIWRR* (in Vietnamese); pp.59-83.

Le Thanh Chuong (2008) Reinforce and improve the sea dyke system from Quang Ngai to Kien Giang provinces. *Final report - SIWRR* (in Vietnamese); pp.9-24.

Liviu Giosan (2014) Protect the world’s deltas. Nature, Volume 516 , 4 December 2014; pp.31-33

Lu X X, Siew R Y (2006) Water discharge and sediment flux changes over the past decades in the Lower Mekong River: possible impacts of the Chinese dams. *Hydrol. Earth Syst. Sci*., 10, 181-195, 2006 www.hydrol-earth-syst-sci.net/10/181/2006/.

NGI (2012) Assessment of land loss in Ca Mau Province, Vietnam. *Main Report*. Norwegian Geotechnical Institute, pp.11.

Phan Anh Tuan(2004) Survey coastal strip morphology variation of South Central and South of Viet Nam. *Final report – SIWRR* (in Vietnamese), pp.29.

Ramesh, R., Chen, Z., Cummins, V., Day, J., D'Elia, C., Dennison, B., Forbes, D.L., Glaeser, B., Glaser, M., Glavovic, B., Kremer, H., Lange, M., Larsen, J.N., Tissier, M.Le, Newton, A., Pelling, M., Purvaja, R., Wolanski, E., Land-Ocean Interactions in the Coastal Zone: Past, Present and Future. Anthropocene http://dx.doi.org/10.1016/j.ancene.2016.01.005.

To Quang Toan (2014) Subjects of the national project: Evaluating the impact of hydropower development plans on Mekong mainstream to the flow, environment, and socio-economy in the Mekong Delta of Vietnam. Final Report (SIWRR) (in Vietnamese); pp.43-51.