Sediment re-deposition in the mangrove environment of Can Gio, Saigon River estuary (Vietnam)

Authors: Schwarzer, Klaus, Thanh, Nguyen Cong, and Ricklefs, Klaus

Source: Journal of Coastal Research, 75(sp1) : 138-142

Published By: Coastal Education and Research Foundation

URL: https://doi.org/10.2112/SI75-028.1

Journal of Coastal Research	SI	75	138-142	Coconut Creek, Florida	2016

Sediment re-deposition in the mangrove environment of Can Gio, Saigon River estuary (Vietnam)

Klaus Schwarzer †, Nguyen Cong Thanh‡, and Klaus Ricklefs††

†Institute of Geosciences, Sedimentology, Coastal and Continental Shelf Research
Kiel University
Kiel, Germany

‡Departament of Oceanography
University of Science
Ho Chi Minh City, Vietnam

††Research and Technology Center Westcoast
Kiel University
Büsum, Germany

www.cerf-jcr.org

www.JCRonline.org

ABSTRACT

Schwarzer, K.; Nguyen Cong Thanh and Ricklefs, K., 2016. Sediment re-deposition in the mangrove environment of Can Gio, Saigon River estuary (Vietnam). *In:* Vila-Concejo, A.; Bruce, E.; Kennedy, D.M., and McCarroll, R.J. (eds.), *Proceedings of the 14th International Coastal Symposium* (Sydney, Australia). *Journal of Coastal Research*, Special Issue, No. 75, pp. 138-142. Coconut Creek (Florida), ISSN 0749-0208.

Sediment re-deposition in mangrove environments is usually attributed to marine and estuarine hydrodynamics - rainfall as a driver was not considered yet. However, combined with annual water level variations, tropical rainfall can play a significant role for sediment re-deposition. Inside mangroves, current velocities induced by rainwater runoff during low tide conditions can be much stronger than tide-induced currents. Along the Saigon River Estuary and the Mekong Delta coastline, rainfall is high from May to October and low from December to April. To study processes controlling sediment re-deposition, data of current and suspended matter concentration have been combined with sediment re-deposition rates. All investigations have been carried out in the Can Gio mangrove reserve, Saigon River mouth. Based on a 19-year data set (1991 – 2009), strong annual variability in water level heights and tidal range are observed, with a mean maximum high tide level of 3.34 m during the rainy season and 3.73 m at the beginning of the dry season. Maximum tidal range is reached during the rainy season coinciding with the lowest annual average sea level. The highest parts of the mangrove forest are not inundated by tides during these periods. Only heavy rainfall during these times can lead to mangrove soil mobilisation, induce strong currents between the mangrove roots and cause erosional gullies. Depending on the amount of precipitation, this sediment mobilisation and the amount of suspension load in the forest can be much stronger than sediment transport induced by tidal currents.

ADDITIONAL INDEX WORDS: *Mangrove forest, Saigon River estuary, suspension solid concentration,*

INTRODUCTION

Mangrove forests are important interfaces between the land and the sea. They mainly grow along sheltered coastlines, estuaries, lagoons and deltaic shorelines within the intertidal domain of tropical and subtropical areas (Woodroffe, 1992). Some of the major functions of mangrove forests include protecting the coastal environment by wave attenuation (Mazda *et al*., 1997, Vo-Luong and Massel, 2006, 2008), reducing coastal erosion (Furukawa and Wolanski, 1996; Mazda *et al*., 1997, 2006; Vo-Luong, 2006; Vo-Luong and Massel, 2006, 2008) and contributing to coastal safety as was observed after the 2004 Indian Ocean tsunami (Danielsen et al., 2005). Additionally, their root system provides a sediment trapping mechanism for suspended particles (Bird, 1971; Wolanski *et al.,* 1986; Augustinus, 1995; Blasco *et al.* 1996; Furukawa and Wolanski, 1996; Thampanya *et al*., 2006; Victor *et al.* 2006). Mangrove environments can keep pace with sea level rise of up to 4.5 mm/year (Gilman *et* 2008) and are growing as a response to an increase in tidal flooding (Anthony, 2004) and sediment supply. Despite these benefits, mangrove environments are under rapid decline worldwide (FAO, 2007; Giri *et al*., 2011). To preserve mangrove forests with all their benefits and to increase awareness, a comprehensive understanding of the physical mechanisms, especially sediment cycling and its relation to hydrological conditions and to seasonal variation, is needed. Our objectives are to provide insight into sediment dynamics in a mangrove forest on time scales from spring-neap tidal cycles to seasonal cycles (dry season versus wet season). We investigate the intertidal sediments forming the forest soil and the suspended matter dynamics in a creek that floods and discharges the mangrove forest.

INVESTIGATION AREA AND METHODS

Due to long-term human impact, the density of mangrove vegetation has considerably changed along the whole southern Vietnamese coastline since the late 19th century, especially in the area of the Dong Nai River estuary, the Mekong delta and the adjacent peninsula towards Ca Mau (Mazda *et al.*, 2002; *Linh K. Phan et al*., 2015). Approximately 42% of the total

DOI: 10.2112/SI75-028.1 received 15 October 2015; accepted in revision 15 January 2016.
*Corresponding author: kls@gpi.uni-kiel.de

mangroves in Vietnam have disappeared from 1980 – 2005 (FAO, 2007).

Investigation area

The forest in the Can Gio reserve is a hybrid between a fringing (F-type) tide dominant and a river dominant (R-type) mangrove forest (Ewel *et al*., 1998). The study site is embedded in the Dong Tranh estuary (Figure 1), a branch of the Saigon River. The tide is mixed, dominantly semi-diurnal. Tidal range varies between almost four metres at spring tide and about only one metre at neap tide. Superposed on daily tidal fluctuations are spring/neap-tidal cycles and monsoon-driven variations in mean water levels (Nguyen, 2012). The depositional environment is characterized by silty sediments. From the banks of the Dong Tranh River and from the banks of the creeks (Figure 1), a morphological gradient exists with a rising bottom towards the inner forest. After the Vietnam War, mangroves have been reforested successfully since 1978, but coastal erosion continued with rates up to 50 m/year in some places (Mazda *et al*., 2002).

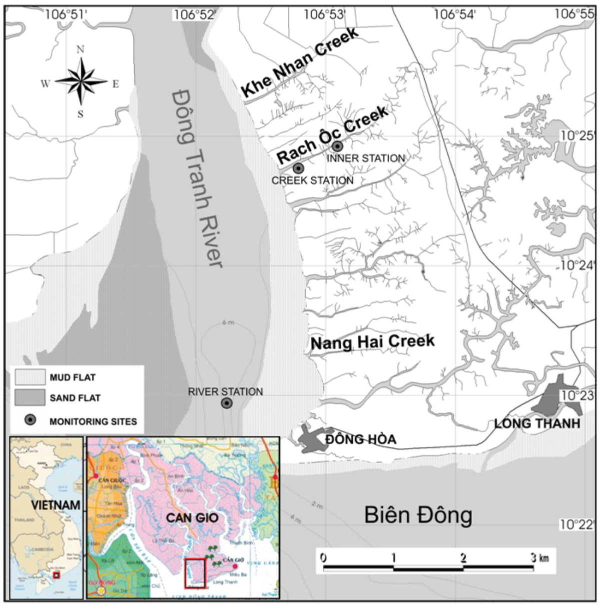

Figure 1. Investigation area with marked hydrological monitoring stations in the Dong Tranh river mouth estuary.

Instrumentation and experimental setup

Measurements of suspended matter concentration (SMC), salinity and temperature were done using optical backscatter sensors (OBS) and stationary conductivity, temperature and water level probes (CTD). OBS (Seapoint Sensors Inc., 2000) transmit an optical signal into the water column of which the wave length is near to infrared light (wave length 880 nm). The intensity of the backscattered light, expressed as a change in output voltage, is understood as measure for the amount of SSC in the water-column. A sensor's response not only depends on the number of scatters but also on the composition and size of the suspended particles. Therefore for precise turbidity measurements an "on site calibration" is needed. The aim of this calibration is to mathematically formulate a close relationship between the sensor's mV response to concentrations of site specific particle composition (mg/l). In our case, prior to a measuring campaign, all available sensors are installed close to each other (Figure 3) at one location for which it is assumed that characteristics are comparable to those of the investigation sites. Calibration lasted for 1 tidal cycle with water sampling every 30 minutes. Samples are filtered (0.63 µm filters) and dried to calculate the total dry mass of suspended matter per volume unit water.

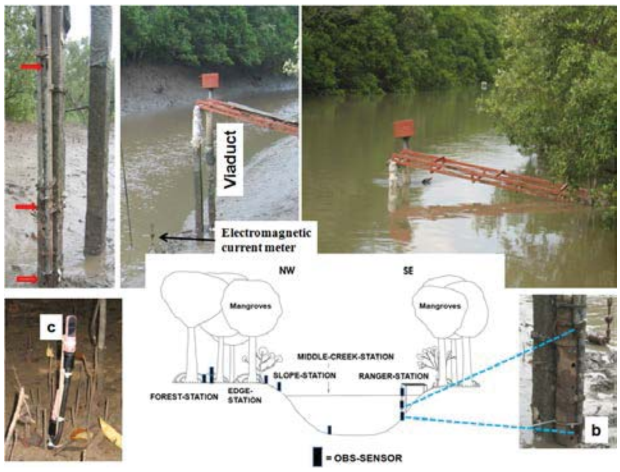

Figure 2. Positions of 9 OBS sensors at the creek station (see Figure 1) in the forest of the Rach Ôc Creek. CTD probes are installed in the creek and in the forest. Red arrows mark OBS-positions at the viaduct.

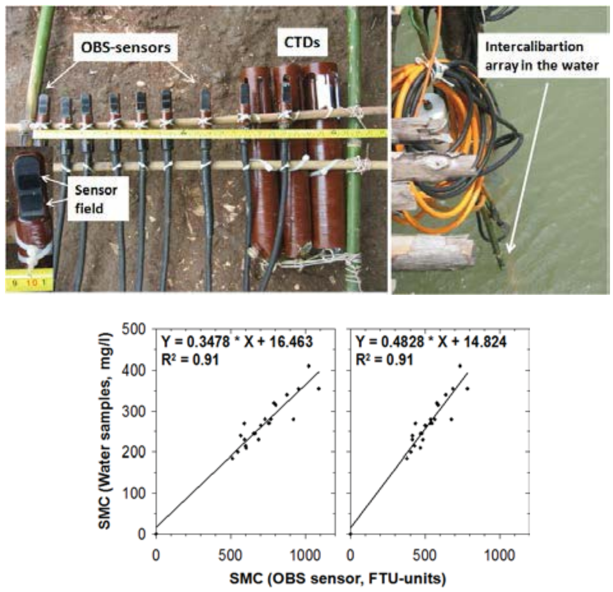

Figure. 3. Sensor-array for the calibration and inter-calibration of OBS sensors and CTD-probes in the field (upper part of this figure). Best fit curves for two OBS sensors from the creek station are shown below.

The relationship between the real concentrations and the sensor's signal strength mostly result in a linear best fit line (Figure 3). The fit equations allow all indirect sensor readings to be converted into real concentration values. The field calibration procedure is also used to inter-calibrate all sensors (Figure 3) and to detect shortcomings of any single sensor.

The instruments are installed in the Rach Ôc tidal creek (Figure 1), at the rim of the forest and in the forest. Time series measurements covered at least one spring/neap tidal cycle. To calibrate the OBS sensors and to carry out particle size analyses, during the field campaign additional water samples were taken every hour at every sensor for at least 1 tidal cycle during neap-, intermediate-, and spring tide.

The SMC measurements were combined with assessments of sediment re-deposition in the mangrove forest by applying the "tracer stick method" (Schwarzer and Diesing, 2001). This method is based on injecting a rectangular stick (length: 10 cm, width: 2 cm) vertically into the sediment. The stick is made up of artificially coloured fine sand which is bound with water-soluble glue. The upper end of the stick coincides with the sediment surface. Upon contact with moisture, the glue dissolves after approximately 5 minutes. The tracer sticks remain in the mangrove soil until recovery where they are subjected to hydrodynamic influences. Erosion and deposition are calculated by measuring the length of the remnant stick with a centimetre scale (Figure 4) immediately after recovery. This method was applied for a 2-year period on 54 stations along the Khe Nhan-, Rach Ôc- and Nang Hai creek (Figure 1). The time the sticks remained in the sediment varied between 2 weeks and 5.5 months.

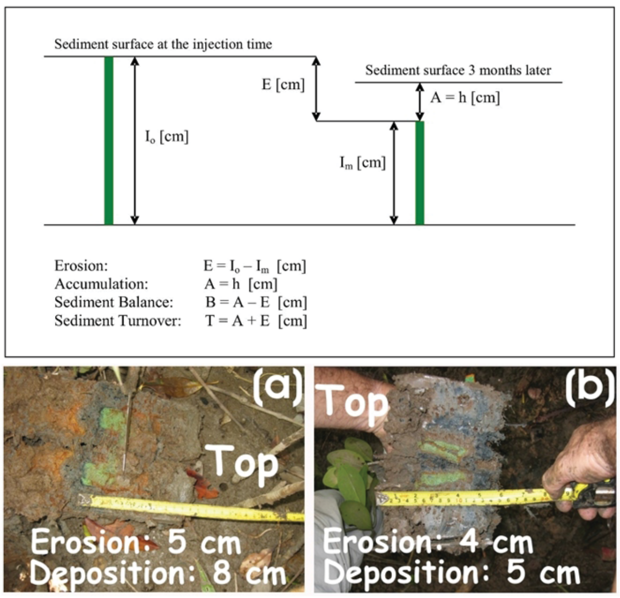

Figure 4. Calculation of sediment erosion, accumulation, balance and turnover. Io = length of the injected tracer stick; lm = length of the remaining tracer stick. In a) and b) the original length of the tracer stick was 10 cm.

Data of water level variations were provided by the Southern Regional Hydro-Meteorological Center (SRHMC) which operates an official tide gauge at Vung Tau, located approximately 20 km east of Can Gio. These data were correlated with our own data, allowing us to extend site specific water level data for a longer period. According to the tidal classification by Courtier (1938), the mixed semi-diurnal tide is characterised by different water levels: two high waters (higher high water (HHW) and lower high water (LHW) and two low waters (higher low water (HLW) and lower low water (LLW)). In addition to these parameters, tidal range (TR) and the mean sea level (MSL) were analysed for the period from 1991 to 2009.

RESULTS

Depending on the monsoon, variations of the considered tidal levels MHHW, MHW, MSL, MLW, and MLLW occur (Figure 5). During the wet season, sea levels are lower than during the dry season. Lowest levels are recorded in June/July (3.34 m), and the highest levels are measured in November (3.73 m). On average, the seasonal differences between highest and lowest MHHW and MLLW are approximately 45 cm and 53 cm, respectively. These values indicate a higher and longer inundation of the mangrove environment during the dry season. On the other hand, due to generally lower high water levels, the highest parts of the mangrove forest will not be tidally flooded during the wet season. This increases the chance for sediment re-deposition in the course of heavy rainfall events.

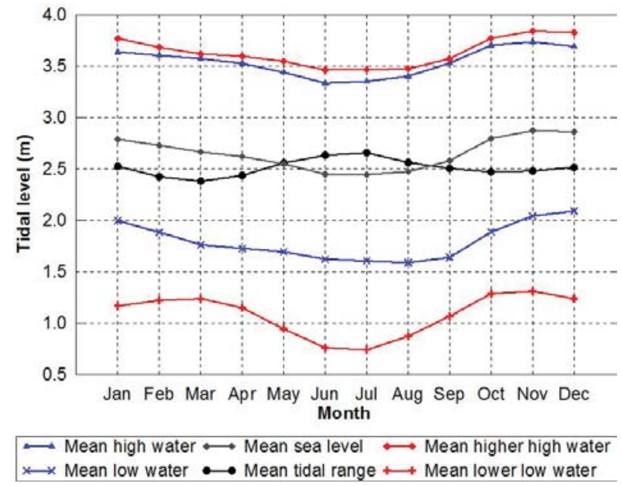

Figure 5. Water level fluctuations at Vung Tau tide gauge based on a 19-years data set (1991 – 2009).

High variability in current velocities, water mass exchange, salinity, suspended matter concentration and sediment erosion and accumulation were found to be attributed to the monsoon cycle. Compared with the dry season, stronger currents combined with more water mass exchange are observed during the wet season, which in addition to intensive rainfall, cause an increase in suspended matter concentrations (Figure 6). If heavy rainfall happens during ebb phase, and the forest soil has already fallen dry, erosion happens and sediments are exported from the forest flats. This is clearly observed in the higher SMC at the creek- and the forest station (Figure 7, sensor b and c). Rainfall during the flood phase does not show any pronounced signal of higher suspension load in the creek. During these phases, either remobilized sediment in the higher part of the mangrove forest due to rainfall will remain in the forest and be distributed there, or the water-level has already reached a height that hampers the ability of raindrops to induce re-suspension.

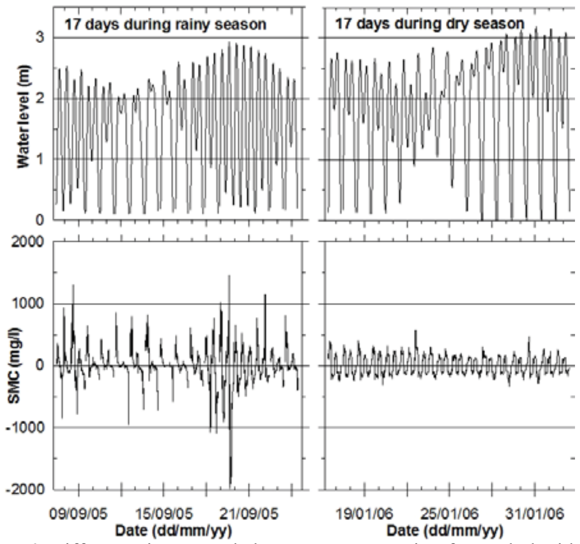

Figure 6. Difference in suspended matter concentration for a whole tidal cycle during the rainy season and the dry season. Data are integrated over all 3 OBS sensors installed at the viaduct in the creek.

Tracer stick data revealed an increase in sediment dynamics combined with higher erosion and accumulation in the mangrove forest during the wet season. Turnover reaches approximately 0.2 cm/day during the wet season, while during the dry season turnover amounts to approximately 0.15 cm/day. The sediment balance during the dry season is negative in the forest with a loss of approximately 0.03 cm/day, while during the wet season the sediment balance in the forest is nearly in equilibrium. During the transitional seasons (May and October/November), the sediment balance is slightly positive with 0.01 cm/day. These findings, combined with the results of SMC measurements at the creek station, indicate that sediment which is washed out from the forest will be transported towards the inside of mangrove forest. Therefore, there is in general a positive sediment budget for this part of Can Gio Mangrove forest.

DISCUSSION

There are only few studies combining investigations of sediment redistribution in mangrove creeks and in mangrove forests. While Horstmann *et al*. (2013) focus mainly on topographical variation and the impact of the vegetation system on flow velocities, we show the impact of monsoon-dependent rainfall combined with seasonal water level fluctuations on sediment mobility. It is known that tidal currents in a mangrove forest rarely reach 0.1-0.2 m/s (Massel, 1998; Furukawa *et al*., 1997; Wu *et al*., 2001). Their ability to initiate short-term high sediment re-deposition rates is small. However, even if the sediment balance is equalized and no changes seem to appear, the sediment turnover, indicating sediment dynamics, can be very high (Figure 4). This turnover might have high implications for geochemical and nutrient cycles in the mangrove environment. Rainfall as a driver has been neglected so far, but should be included in future studies.

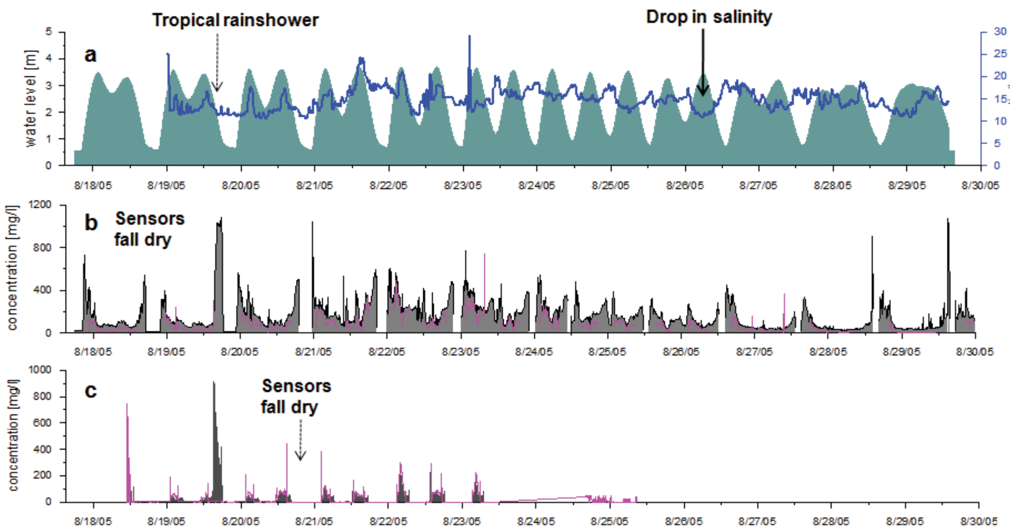

Figure 7. Suspension load concentration measured at different stations in a creek cross-section. The upper figure (a) shows salinity and tidal variation. Tropical rainfall during ebb tide increases the suspension load at the sensors b and c (for position see Figure 2), while a drop in salinity during flood tide, which is an indicator for rainfall, shows now increase in suspension load in the creek and close to the creek (see text for further explanation).

CONCLUSIONS

Sediment re-deposition in the mangrove environment of Can Gio shows seasonality in tidal- and water level fluctuations and precipitation. When rainfall happens during ebb tide, strong currents are initiated all over the mangrove environment as rain-water follows the morphological gradient, creating small gullies. This current induced sediment mobility and the amount of suspension load can be much higher compared to tide induced suspension load in the forest. Sediment turnover (see Figure 4) is an indicator for sediment dynamics. Even if the sediment balance is close to zero, sediment dynamics can be rather high.

ACKNOWLEDGMENTS

This study was funded by the German Research Foundation (DFG) grant SCHW 572/8-1, 2 and by the Ministry of Science and Technology (MOST), Vietnam. We thank our colleagues La Thi Cang for providing us with data from the SRHMC, to Daniel Unverricht and Le Xuan Thuyen for suggestions and comments and to Patrycja Czerniak for field assistance.

LITERATURE CITED

Anthony, E., 2004. Sediment dynamics and morphological stability of estuarine mangrove swamps in Sherbro Bay, West Africa. *Mar. Geol*., 208, 207- 224.

Augustinus, P.G.E.F., 1995. Geomorphology and sedimentology of mangroves. *In*: Perillo, G.M.E. (ed.). *Geomorphology and Sedimentology of Estuaries. Developments in Sedimentology*, 53, Amsterdam: Elsevier, pp. 333-357.

Bird, E.C.F., 1971. Mangroves as land builders. *Nature*, 88, 189-197.

Blasco, F.; Saenger, P., and Janodet, E., 1996. Mangroves as indicators of coastal change. *Catena*, 27, 167-178.

Courtier, A., 1938. Marées, Service Hydrographique de la Marine, 284 pp.

Danielsen, F.; Sørensen, M.K.; Olwig, M.F.; Selvam, V.; Parish, F.; Burgess, N.D.; Hiraishi, T.; Karunagaran, V.M.; Rasmussen, M.S.; Hansen, L.B.; Quarto, A., and Suryadiputra, N., 2005. The Asian tsunami: a protective role for coastal vegetation. *Science*, 310, 643.

Ewel, K.C.; Twilley, R.R., and Ong, J.E., 1998. Different kinds of mangrove forest provide different goods and services. *Global Ecology and Biogeography Letters*, 7(1), 83 – 94.

FAO, 2007. The world's mangrove 1980 – 2005. Food and Agriculture Organization of the United Nations Forestry Paper, 153, 74 pp.

Furukawa, K. and Wolanski, E,. 1996. Sedimentation in mangrove forests. *Mangroves and Salt Marshes*, 1(1), 3-10.

Furukawa, K.; Wolanski, E., and Muller, H., 1997. Currents and sediment transport in mangrove forests. *Estuarine, Coastal and Shelf Science*, 4, 301-310.

Gilman, E.L.; Ellison, J.; Duke, N.C.J., and Field, C., 2008. Threats to mangroves from climate change and adaption aptions: A review. *Aquatic Botany*, 89 (2), 237 - 250.

Giri, C.; Ochieng, E.; Tieszen, L.L.; Zhu, Z.; Singh, A.; Loveland, T.; Masek, J., and Duke, N., 2011. Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography*, 20, 154 – 159.

Horstmann, E.M.; Dohmen-Janssen, C., and Hulscher, S.J.M.H., 2013. Flow routing in mangrove forests; a field study in Trang provinve, Thailand. *Continental Shelf Research*, 71, 52 – 67.

Linh K. Phan; Jaap, S.M.; van Thiel de Vries and Stive, M.J.M, 2015. Coastal Mangrove Squeeze in the Mekong Delta. *Journal of Coastal Research*, 31 (2), 233 – 243.

Mazda, Y.; Magi, M.; Kogo, M., and Hong, P.N., 1997. Mangroves as a coastal protection from waves in the Tong Kinh Delta, Vietnam. *Mangroves and Salt Marshes*, 1(2), 127 – 135.

Mazada, Y.; Magi, M.; Nanao, H.; Kogo, M.; Miyagi, T.; Kanazawa, N., and Kobashi, D., 2002. Coastal erosion due to long term human impact on mangrove forests. *Wetlands Ecology and Management*, 10, 1 – 9.

Mazda, Y.; Magi, M.; Ikeda, Y.; Kurokawa, T., and Asano, T., 2006. Wave reduction in a mangrove forest dominated by Sonneratia sp. *Wetlands Ecology and Management*, 14 (4), 365-378.

Nguyen C.T., 2012. Processes and factors controlling and affecting the retreat of mangrove shorelines in South Vietnam. PhD thesis, Kiel University, Institute of Geosciences, 130 pp.

Schwarzer, K. and Diesing, M., 2001. Sediment Redeposition in Nearshore Areas - examples from the Baltic Sea. *Proceedings of the Conference Coastal Dynamics '01* (Lund, Sweden), 808 – 817.

Thampanya, U.; Vermaat, J.E.; Sinsakul, S., and Panapitukkul N., 2006. Coastal erosion and mangrove progradation of Southern Thailand. *Estuarine, Coastal and Shelf Science*, 68, 75-85.

Victor, S.; Neth, L.; Golbuu, Y.; Wolanski, E., and Richmond, R.H., 2006. Sedimentation in mangroves and coral reefs in a wet tropical island, Pohnpei, Micronesia. *Estuarine, Coastal and Shelf Science*, 66, 409-416.

Vo-Luong, H.P., 2006. Surface waves propagation in mangrove forest and induced suspended sediment concentration. PhD thesis, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland, 191pp.

Vo-Luong, H.P. and Massel, S.R., 2006. Experiment on wave motion and suspended sediment concentrations at Nang Hai, Can Gio mangrove forest, southern Vietnam. *Oceanologia*, 48(1), 23 – 40.

Vo-Luong, H.P. and Massel, S.R., 2008. Energy dissipation in non-uniform mangrove forests of arbitrary depth. *Journal of Marine Systems*, 74(1-2), 603 – 622.

Wolanski, E. and Ridd, P., 1986. Tidal mixing and trapping in mangrove swamps. *Estuarine, Coastal and Shelf Science*, 23, 759-771.

Woodroffe, C.D., 1992. Mangrove sediments and geomorphology. *In*: Robertson, A.I. and Alongi, D.M. (eds.), *Tropical Mangrove Ecosystems*. Coastal and Estuarine Studies. American Geophysical Union, pp. 7- 41.

Wu, Y.; Falconer, R.A., and Struve, J. 2001. Mathematical modelling of tidal currents in a mangrove forest. *Environmental Modelling and Software*, 16(1), 19 – 29.