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INNOVATIVE VIETNAMESE RESEARCH ON MEKONG DELTAIC COASTAL PROCESSES

M.J.F. Stive[1], L.K. Phan[2], S.T. Truong[2], H.M. Phan[3] and H.T. Dao[4]

ABSTRACT: Over the last few decades, the Mekong Delta Coast has undergone many physical changes that have increased its vulnerability. Issues that have grown in importance are erosion, human occupation of coastal and estuarine mangroves, decreased sediment supply by the Mekong River and subsidence due to groundwater extraction. These issues have led to the loss of coastal and estuarine land and mangroves, increasing flood vulnerability and salinity intrusion. Recently, young and promising Vietnamese researchers have undertaken a number of in-depth studies to increase our understanding of the above issues. The objective of the present paper is to give a concise description of their work and place it into a broader context. The topics concerned are satellite mapping of coastal landuse changes, numerical simulation of the tide and wave climate and of coastal erosion, coastal and estuarine mangrove squeeze, wave and current damping in mangroves and wave transmission through bamboo fences. The main findings are that (1) coastal landuse has changed significantly over the last decades with the largest change due to conversion of mangroves to aquaculture and a modest change due to coastal erosion, (2) the understanding of the tide and wave climate and of the erosion has increased due to successful numerical modelling, (3) the role of mangrove squeeze along the coast and along the estuaries has been assessed, (4) the understanding of wave and current damping in mangroves and of wave transmission through bamboo fences has increased through the combined effort of laboratory and numerical modelling.

Keywords: Mekong Deltaic Coast, coastal land-use change, tide modelling, wave modelling, mangrove erosion, mangrove squeeze, wave transmission.

INTRODUCTION

Over the last few decades, the Mekong Delta Coast has undergone many physical changes that have increased its vulnerability. Issues that have grown in importance are erosion, human occupation of coastal and estuarine mangroves, decreased sediment supply by the Mekong River and subsidence due to groundwater extraction. These issues have led to the loss of land and mangroves, increasing flood vulnerability and salinity intrusion.

Recently, several young Vietnamese researchers have undertaken a number of in-depth studies to increase our understanding of the above issues. The objective of the present paper is to give a concise description of their work. The topics concerned are satellite mapping of coastal landuse changes, numerical simulation of the tide and wave climate and of coastal erosion, coastal and estuarine mangrove squeeze, wave and current damping in mangroves and wave transmission through bamboo fences.

Obviously, these topics cover only a small portion of all relevant processes related to the Mekong Deltaic Coast (MDC), but is yet considered as an essential basis for the implementation of management interventions and the formulation of appropriate research.

SATELLITE MAPPING OF COASTAL LANDUSE CHANGE

Since the area of mangroves in MDC is not well documented, the study of Phan and Stive (2019) aimed to quantitatively document the evolution of the mangrove area over the past 43 years (between 1973 and 2015). Satellite Landsat Images have been used for mapping land cover types. This includes mangroves, soils, aquaculture, plants and water surfaces along the coastal districts of the Mekong Delta. The study shows that remote sensing and GIS techniques can be applied to obtain a mapping of the land cover, as well as to detect and analyse spatial and temporal changes caused by, e.g. aquaculture expansion or coastal erosion. The findings reveal that the total mangrove area of an estimated 186,000 ha in 1973 decreased significantly to 96,000 ha in 2015, hence a halving approximately. Approximately 2170 ha/yr of the total mangrove loss over 1973-2015

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[1] Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, the Netherlands
[2] Faculty of Civil Enineering, Thuyloi University, Hanoi Vietnam
[3] Institute of Coastal and Offshore Engineering, Vietnam Academy for Water resources, Ho Chi Minh, Vietnam
[4] Hanoi University of Natural Resources and Environment, Hanoi, Vietnam

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was caused by conversion to aquaculture, while approximately 430 ha/yr was lost due to coastal erosion. A slight increase in mangrove area occurred since 2010 as a result of the implementation of a series of projects to protect against coastal erosion and to restore mangroves by the Vietnamese government and international non-governmental and governmental organizations, although the success rates are relatively low. The reasons behind these changes are the subject of the remaining part of this paper.

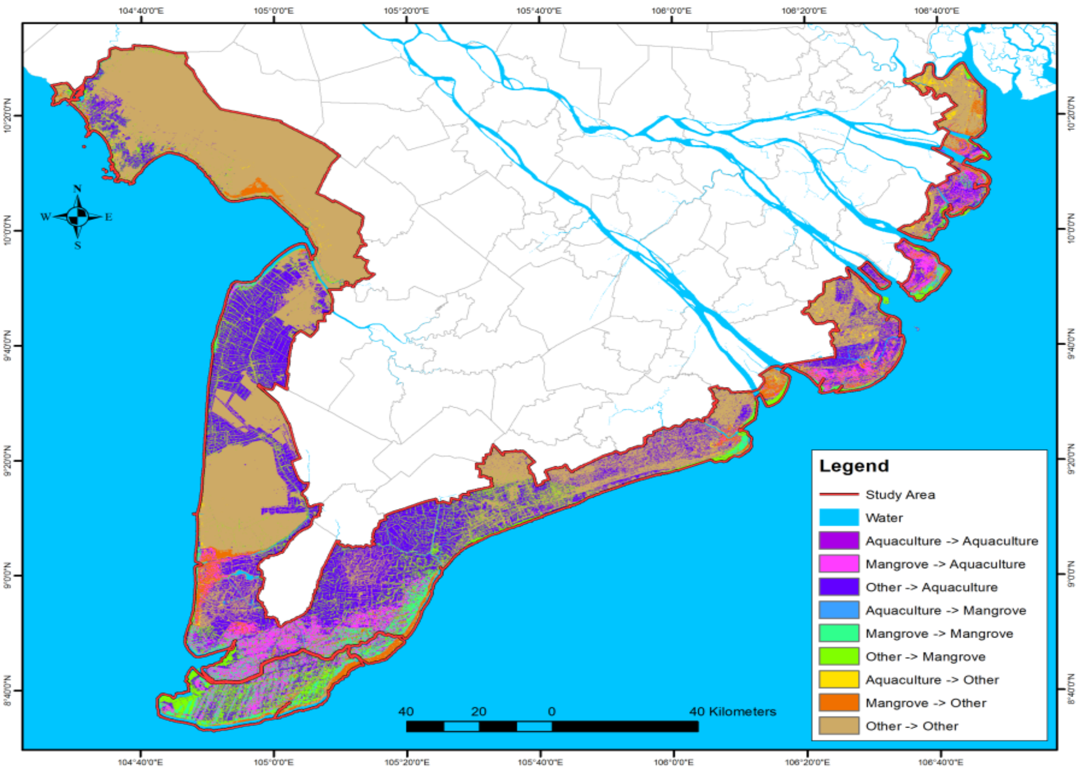

Figure 1. Conversion dynamics of mangrove and aquaculture from 1973 to 2015; 'Other' refers to land cover of non-determined plants and soils types (from Panh and Stive, 2019)

NUMERICAL SIMULATION OF TIDES AND WAVES

Since tidal information along the Mekong Deltaic Coast is not well known and/or analyzed, Phan et al. (2019a) constructed a two-dimensional, barotropic model to investigate the dynamics of tidal wave propagation in the South China Sea with particular emphasis on the characteristics along the Mekong Coast. Amongst others, it is explained for the first time why a diurnal tide dominates along the Western Mekong Delta Coast and a semi-diurnal tide along the Eastern Mekong Delta Coast by using Green's law, the formula of tidal continental shelf resonance and the theory of standing waves. Besides, this study also detected the radial tidal current systems on the southern Mekong deltaic shelf (see Figure 2).

Similarly, detailed wave information along the MDC is also not well-known and/or analyzed. Phan et al. (2019b) numerically simulated the wave climate using the spectral wave model SWAN forced by wind fields produced by the National Oceanic and Atmospheric Administration (NOAA). It is shown how different the wave forcing is between the East and the West MDC under the wind monsoon climate system. Whereas the wind fields in the winter monsoon climate only influence wave fields on the eastern coast due to the limited fetch length at the western coast, the wind system in the summer monsoon climate has a considerable influence on both the eastern and western coasts.

BULK LONGSHORE SEDIMENT TRANSPORT AND COASTAL EROSION

Based on the simulations of tides and waves, Phan et al. (2019b) derived the bulk longshore sediment transport capacity according to the CERC formula. The gradients in this transport capacity were used to reveal erosion and accretion qualitatively and quantitatively. The study also indicates that the unbalanced seasonal potential LST gradients lead to a similar pattern of erosion and accretion in the coastal areas of the eastern estuarine zones. Comparison with field observation over the 43-year period showed a good correspondence in a qualitative sense but generally an underestimation in a quantitative sense. A number of hypotheses for not-considered processes were posed to explain the underestimation.

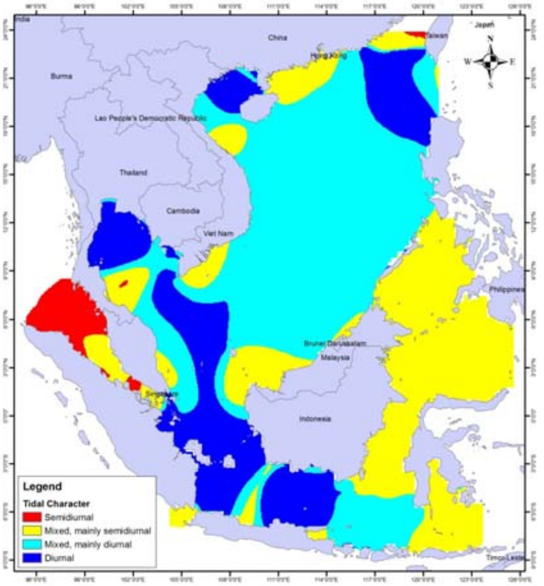

Fig.2: Tidal characteristics in the South China Sea (also called East Sea) and the adjacent Seas (from Phan et al, 2019).

COASTAL AND ESTUARINE MANGROVE SQUEEZE

The topic of coastal and estuarine mangrove squeeze is addressed in Phan et al. (2015) and Truong et al. (2017). In these studies, the hypothesis was researched that the human occupation of mangroves by aquaculture may lead to coastal and estuarine erosion even when the availability of sediment (from the estuarine and/or coastal system) is not a limiting factor. For locations that fulfilled this last condition, these studies derived the results given in Figures 3 and 4.

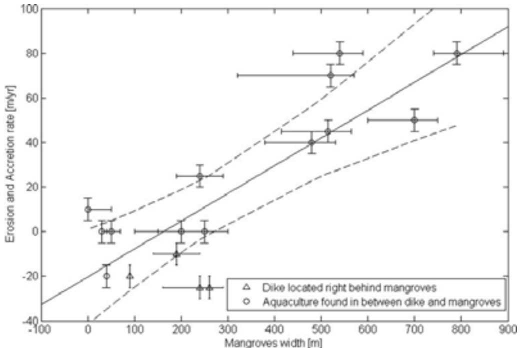

Fig.3: The relation between mangrove width and coastline behaviour along the east coast of the MDC (assuming the availability of sediment is not a limiting factor) (from Phan et al., 2015).

The basic assumption behind both studies is that there exists a critical width of a mangrove strip both along the coast and the estuaries to keep its ability to remain stable or, once surpassing the minimum width, to promote sedimentation.

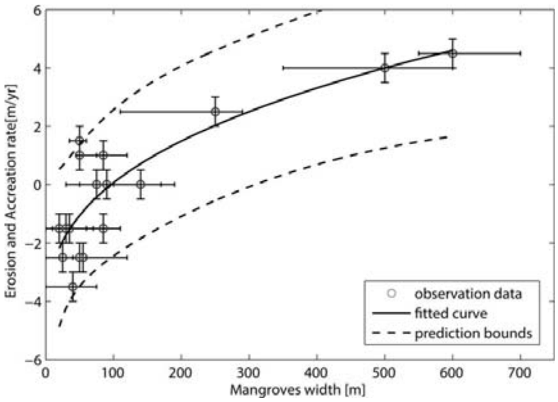

Fig.4: Relation between mangrove forest width and riverbank evolution in the MDC (assuming the availability of sediment is not a limiting factor) (from Truong et al., 2017).

For the East Coast of the MDC, the critical width is around 140 m, while for the estuaries it is approximately 80 m.

WAVE DAMPING IN MANGROVES

While many studies have been published on the topic of wave damping in mangroves, the findings are extremely variable. In order to increase our insights, a laboratory experiment mimicking the attenuation of waves in mangroves was conducted (Phan et al., 2019c). To quantify the damping induced by vegetation a new method was presented. The wave height attenuation is given over a relative length-scale (viz. the number of wavelengths) instead of over an absolute length-scale. This resulted in a more coherent picture, while it was also found that the degree of wave non-linearity has a strong influence in that the more non-linearity, the stronger the damping.

Figure 5 shows the relationship between the effective wave transmission coefficient and the Ursell number for a different number of wave lengths. It can be clearly seen that as the Ursell number increases, K_L (the ratio of incoming wave height and damped wave height) reduces, which implies an increase in wave reduction. This means that the wave dissipation by vegetation appears to be more effective as the waves are more non-linear. Moreover, as the Ursell number increases to above 150, the declination of the K_L reduces. K_L appears to achieve an equilibrium value when the Ursell number is larger than 250. This means that the wave height reduction no longer depends on the wave non-linearity. This characteristic can be observed for both regular and irregular waves (Phan et al., 2019c).

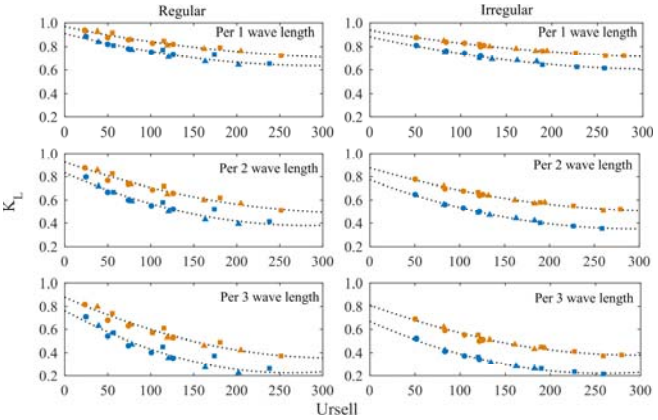

Fig.5: Relationship between the effective transmission coefficient K_L and Ursell number for different wave height and periods: T_p = 2 second (circles), T_p = 2.5 second (triangles), T_p = 3 second (squares), different mangrove densities: sparse (orange), dense (blue) per one wave length (upper panels), per two wave lengths (middle panels), per three wave lengths (upper panels). The trend lines (dot lines) are second order polynomial lines (From Phan et al., 2019c)

CURRENT DAMPING IN MANGROVES

Over the last decade, the impact of vegetation on the hydrodynamics of floodplain vegetated channels has been well recognized. A most interesting feature is the occurrence of large coherent flow structures at the interface of the open and vegetated channel flow region. However, it is not clear how the presence of vegetation affects the large coherent structures and how this contributes to the exchange processes between the open channel and the adjacent floodplain. In order to obtain more insight, a unique laboratory experiment of a shallow flow field in a vegetated compound channel, mimicking a mangrove floodplain in an estuary, has been conducted (Truong et al., 2019). The results show that the presence of vegetation does significantly change the flow field of the compound channel. It generates stronger velocity gradients, promotes the presence of large coherent structures and increases, thereby the momentum exchange with the vegetated regions.

Figure 6 illustrates the representative experimental results. Quoting Truong et al. (2019): "*As the LHCSs move along with the vegetation interface, they generate cycloid flow events, which are composed of sweeps, ejections, stagnant and reverse flows. These flow events then divide the shallow flow field of a vegetated compound channel with a gentle slope into three main different regions, which are driven by different physical parameters and have different length scales (Figure 6a). The uniform region in the main channel (region II) is controlled by the bottom friction (Cf), the corresponding length scale is the water depth (Dc). The uniform region inside the floodplain (region I) is controlled by the drag force (C_{da}) caused by the vegetation. The relevant length scales are the cylinder diameter (d) and the distance between cylinders (s), and the water depth (Df). In between these regions the mixing layer (region III and IV), is governed by the LHCSs. The corresponding length scales in this region are the width of the penetration into the vegetation, the outer layer width and the water depth (D(y)). The presence of LHCSs is the key factor in the mixing layer determining the transverse exchange of momentum*

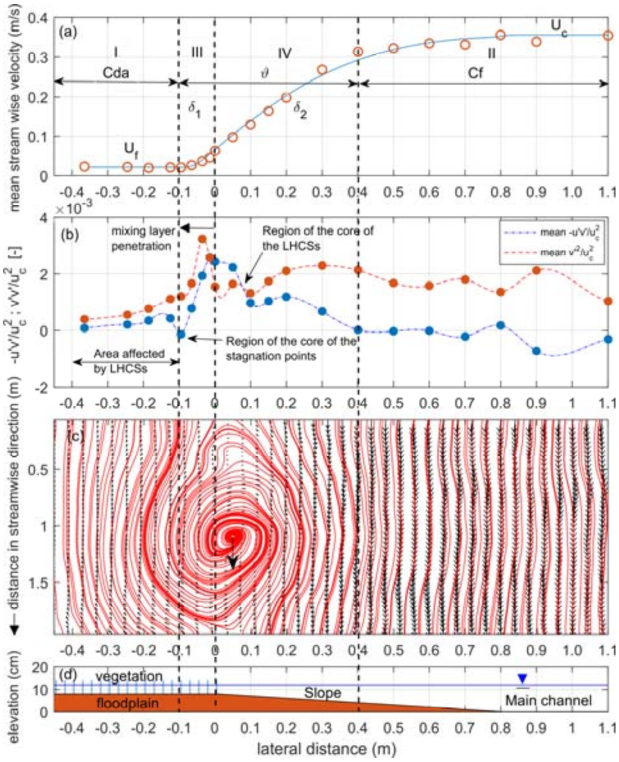

Fig.6: representative mean streamwise velocity in cases with vegetation (a). Representative comparison between the normal and shear stresses in the vegetated compound channel induced by the lhcss (b). The representative lhcss captured through the streamlines of the instantaneous fluctuating velocity field and its corresponding effect on the mean streamwise velocity (c). Dense scenario, 50 cm floodplain width, discharge = 45l/s; water depth = 12 cm. (From Truong et al., 2019)

between the open region (II, IV) and the vegetated region (I, III). *It is suggested that the increased drag due to vegetation can substantially reduce the local flow velocity, thereby increasing the velocity gradient between the adjacent open channel and the vegetation region, withdrawing more momentum towards the floodplain vegetated region*."

WAVE TRANSMISSION THROUGH BAMBOO FENCES

In the Mekong Delta, as in many other mangrove settings, wooden fences are considered as beneficial coastal structures to provide sheltering for mangrove replantation efforts by reducing waves and currents and promoting sedimentation. One of the most quantitative previous studies on fence-induced wave reduction offers only a limited understanding of relevant process parameters. The application of the advanced numerical time-domain model SWASH by Dao et al. (2018) is shown to increase this understanding substantially and explains the anomalies encountered in previous studies. The findings confirm that wave damping increases with increasing fence thickness and with increasing density. These findings also reveal that damping scales with the dimensionless fence thickness, and that nonlinear waves, represented by the Ursell number, are damped more effectively.

CONCLUSIONS

The topics discussed are satellite mapping of coastal landuse changes, numerical simulation of tide and wave climate and of coastal erosion, coastal and estuarine mangrove squeeze, wave and current damping in mangroves and wave transmission through bamboo fences. The main findings are that (1) coastal landuse has changed significantly over the last decades with the largest change due to conversion of mangroves to aquaculture and a modest change due to coastal erosion, (2) the understanding of the tide and wave climate and of the erosion has increased due to successful numerical modelling and the qualitative pattern of erosion and accretion was successfully reproduced, (3) the role of mangrove squeeze along the coast and along the estuaries has been assessed and in cases where sediment availability was not a limiting factor a minimal critical width was found to ensure the health of mangroves, (4) the understanding of wave and current damping in mangroves and of wave transmission through bamboo fences has increased through the combined effort of laboratory and numerical modelling and quantitative understanding of the minimal critical width and of the transmission processes was produced.

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