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Impacts of dyke development in flood prone areas in the Vietnamese Mekong Delta to downstream flood hazard

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Flooding in the Mekong Delta is an annual phenomenon causing inundation of large parts of the delta. This flooding is vital for the geomorphological stability of the delta, but is also the backbone of the highly productive agro-economy. However, extraordinary high floods are on the other hand a major hazard for the millions of people living in the delta. Therefore large scale developments of hydraulic structures took place in the Vietnamese part of the delta in the last decades. Particularly in the areas prone to deep and long lasting inundations many flood protection structures, mainly dykes, were built. These structures enable a blocking of inundation in large parts of these areas and by this the cropping of a third crop per year during the flood season. However, these structures are frequently blamed for increasing water levels in the areas downstream. Thus this study aimed at the investigation and attribution of changes in flood hazard in the Vietnamese Mekong Delta (VMD) due to high-dyke construction in deep flood prone areas, mainly in An Giang and Dong Thap provinces.

This analysis started with the estimation of monotonic trends at key gauging stations in the delta: Kratie at the apex of the Mekong delta; Tan Chau and Chau Doc in the VMD just upstream of the areas with high-dyke construction; and Can Tho and My Thuan, located downstream of the high-dyke areas. The tests were undertaken assuming different magnitudes of errors in the data using historical records from 1978 – 2015, using the Mann-Kendall test and Sen's slope estimation. The obtained trends were thus tested for robustness against data errors. In order to obtain a better understanding of trends in the flood dynamics, the tests are performed on both flood peak and flood duration. In addition, the Pettitt test was applied to identify step changes in the water level data at 4 gauge stations located in the VMD. After the trend analysis, the impacts of high-dyke development were quantified with the help of a quasi-2D hydrodynamic flood inundation model, using the latest comprehensive dyke survey and topographical data for the VMD. Changes in delta inundation dynamics with-/without- high-dyke systems were investigated in two different model setups, simulating the two recent most severe flood events in 2000 and 2011 with their original dike system as reference, and interchanged dyke system in order to quantify the induced hydraulic changes. In a similar manner the specific influence of the upper boundary, i.e. the flood characteristics of the two events, and the lower boundary, i.e. the tidal influence, on the water levels in the VMD was quantified and compared to the influence of the dyke system.

Results of the trend test revealed negative but low significant trends at Chau Doc ($p \geq 0.1$) and Tan Chau ($p \geq 0.05$) at the upper part of the delta within the studied period. On the contrary, strong increasing and highly significant trends were detected at Can Tho and My Thuan downstream of fully flood protection areas, with a step change around the year 2000 ($p < 0.001$). Of which, an increase of $\sim$9.0$\div$13.0 cm in flood peak and $\sim$10 days in duration were attributed to high-dyke development upstream as results of the model simulation. We also found that the most dominant factor altering flood dynamics at these locations are changes of lower boundaries, causing differences of about +19.0 cm and +32.0 cm at My Thuan and Can Tho respectively for the two flood events. The third considered factor, influence of changing of inflow, was mostly dominant in the upper parts of the VMD. It was accounted for $\sim$7$\div$8 cm of total water level alteration in the middle parts of the delta, compared to about -27 cm at the border of Vietnam and Cambodia. Thus the claims that the dyke development has altered the water levels during floods in the areas downstream can be confirmed, but it has to be noted that the lower boundary, i.e. higher sea levels caused by sea level rise in combination with the widely observed land subsidence have an even larger impact. Based on these results, it is recommended to develop flood risk management strategies that use the high dyke areas as retention areas in order to mitigate the flood hazard downstream, if large flood events are forecasted.