Acknowledging the Fragility of Sediment-Starved Deltas

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Introduction: Deltas result from the balance between sediment supplied from the river basin and processes of subsidence and coastal erosion. Many deltas are geologically recent features, and changes in the river sediment budgets can cause them to retreat and subside as their sediment loads are reduced or cut off by upstream dams (and other changes). In transboundary river systems, it may be difficult for managers to fully understand how the coastal landform depends upon processes extending upstream in the basin, especially as there may be a lag of years or decades between reductions in sediment supply and resulting geomorphic responses downstream. Moreover, many deltas are population centers and hotspots of economic activity, making it difficult for us to conceive of their disappearance in the near future. How well have planning efforts acknowledged the dependence of delta landforms on their sediment supply, and the possibility of their demise if sediment supply is cut off? The Mekong Delta provides a compelling illustration of this challenge to river basin management.

Changing Sediment Supply to the Mekong Delta: The Mekong Delta prograded 250km to its present extent over the past 7000 years, built by the river's natural sediment load of 140-160 Mty $^{-1}$. However, if all proposed dams (>140) are built, they will trap 96% of the sediment formerly reaching the delta [1]. The remaining sediment load is further reduced by in-channel mining of an estimated 54 Mty $^{-1}$ of sand (about 10X the river's current sand load) for construction and land reclamation [2]. Within the Delta, distributary channels formerly overflowed, spreading sediment-laden flood flows across the delta, but dikes now restrict sediment-charged floodwaters to the main channels and send the sediment load out to sea. Natural mangrove vegetation traps sediment to build up delta land, absorbs wave energy, and reduces coastal erosion. However, the Delta's mangroves largely have been replaced by agriculture and aquaculture, and the remaining mangroves are now starved of sediment to trap.

The Mekong Delta is low-lying, mostly below 2m elevation. Combining the various drivers (sediment starvation, subsidence, sea level rise), and assuming continuation of 'business as usual', results in a relative subsidence of up to 1.8m, which would submerge 90% of the delta. In contrast, a best-case scenario (strongly curtailed pumping, mining, and dam construction) could limit subsidence to 0.15m, inundating about 10% of the delta [3].

Planning for the Delta's Future: Although government agencies, funders, and other decision makers have recognized many of the problems resulting from these trends, no major planning or policy instrument has yet acknowledged that most of the delta might fall below the sea-level within a human lifetime. The Mekong Delta Master Plan frames flooding, salinity, and coastal erosion as problems to be addressed, but treats them as individual and local problems, rather than symptoms of underlying causes, spanning from local to basin scales. The Plan reports ongoing subsidence rates but neither extrapolates these rates to the end of the century, nor acknowledges the existential threat to the delta. This gap in management persists in more recent plans, such as the Mekong Delta Integrated Regional Plan, proposed to the Vietnamese Ministry of Planning and Investment in July 2020, and in large-scale investments by international actors. The World Bank will invest nearly US$2 Billion through 2022, much of this to address the impacts that a sinking delta creates on the livelihoods of its inhabitants, e.g., by protecting against local flooding and coastal erosion, or by dealing with salinized water supplies. However, none of the many plans and investments extrapolate subsidence rates to 2100, and thus none acknowledges the long-term existential risks to livelihoods and investments. In 2020, the Vietnamese government established the Mekong Delta Regional Coordination Council to implement the 2017 Resolution 120 on 'Sustainable and Climate-Resilient Development of the Mekong Delta of Viet Nam'. While a step in the right direction, the resolution does not recognize that the very existence of the delta landform is in doubt, nor lay out steps to address basin-wide drivers through transboundary action.

The Mekong illustrates the difficulty for decision makers to acknowledge existential threats to sediment-starved deltas, as also manifest with other deltas, such as the Mississippi. Understanding changes to sediment budgets at a basin scale is prerequisite to acknowledging the true threat posed to sediment-starved deltas globally.

References: [1] Kondolf et al (2014) *Wat Res Res* 50 doi:10.1002/2013WR014651 ; [2] Bravard et al. (2013) *EchoGéo* **26**: 13659; [3] Kondolf et al (2018) *Sci Total Env* **625** :114-134