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Balancing hydropower production and sediment delivery via robust planning of dam portfolios under competing effects of dam sediment trapping and land use change

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Fluvial sediment budgets and sediment delivery to river deltas are strongly impacted by human activities, including sediment trapping in dams or alterations of soil erosion due to land use change. Predictions regarding direction and magnitude of these changes are often highly uncertain due to poorly quantified processes and unknown future strategic planning decisions. In this work, we contribute a novel robust planning approach to balance hydropower production and sediment delivery to river deltas under alternative future scenarios of dam development and land use change. The Mekong River basin is used to demonstrate the proposed approach.

The Mekong Delta was built during the Holocene by a constant sediment delivery of approximatively 160 MT/year from the basin, creating a 40,000 km2 subaerial landform that currently sustains a population of 17 million people and a wide range of ecosystem services. The Delta is mostly less than 2m above sea level, so it is extremely vulnerable to changes in its sediment budget. Recently, the rapid economic development of the six riparian nations (China, Myanmar, Laos, Thailand, Cambodia, and Vietnam) increased the energy demand of the region triggering a major hydropower expansion. Yet, hydropower development in the basin will lead to large trapping of sediment (likely 96% trapped for the full built-out), which will largely cut off sediment delivery to the Delta. On the other hand, population growth and agriculture expansion are expected to increase erosion and sediment yield from the basin.

To quantify the vulnerability of the Mekong Delta to future scenarios of hydropower development and land use change, we first generate a large ensemble of sediment yields from the basin's geomorphic regions as produced by plausible land use change. We combine this ensemble with alternative hydropower portfolios to estimate the joint effect of the two competing drivers. Results show that a few geomorphic regions control most of the delta sediment delivery, but their ranking depends on the simulated dam development scenario.

Then, we explore the robustness of the hydropower portfolios against land use change scenarios. Numerical results show that the existing dams produce a significant reduction of sediment transport to the delta for all the generated land use scenarios. Moreover, if dam building continues as planned, a critical reduction in sediment flux to the delta is immanent in the near future. We demonstrate that alternative hydropower portfolios that can provide similar energy production levels with lower impacts on sediment delivery, thus making the Mekong Delta more robust against a wide range of future scenarios.