POLICY FORUM

RIVER GOVERNANCE

Save the Mekong Delta from drowning

Policy must address drivers, not just symptoms, of subsidence

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Owing to only a few decades of human influence and unsustainable management of the Mekong River basin's natural resources, the Mekong Delta is receding rapidly. Most of the delta landform, home to 17 million people and an economic powerhouse, could slip below sea level by 2100 (*1*). Avoiding such a catastrophic impact will require concerted actions that acknowledge root causes for land loss and the global importance of the delta landform. Deltas persist and grow if sediment supply from an upstream river basin builds delta land at the same or greater rates than land is submerged by relative sea level rise and erosion. With more rapid sea level rise, more sediment resources are needed to maintain the current extent of the delta. Only improved coordination of governance and investments, informed by science, will provide the delta with those critical resources.

The Mekong Delta, which lies mostly in Vietnam, is one of the world's largest deltas. The delta has been transformed in the past century into a human-made landscape, or "Delta Machine" (*2*), which produces 7 to 10% of all rice traded internationally. The delta averages less than 1 m above sea level, so it is vulnerable to subsidence and coastal erosion. Many initiatives have supported local adaptation measures to address symptoms of a sinking delta, but have not addressed underlying anthropogenic drivers of subsidence at both the delta and basin scales, nor considered the international nature of the basin.

Prior to the late 20th century, the delta received 140 to 160 million metric tons (Mt) of sediment annually from the Mekong River basin. More than half of this is now being trapped in reservoirs. In the upper Mekong basin in China (the Lancang), eight large hydropower dams have been completed, with another 20 under construction or planned. In the Mekong, 133 dams are built or planned, of which 11 are on the mainstem of the lower Mekong. If built as planned, all dams will trap 96% of the sediment formerly reaching the delta (*3*). Additionally, sediment supply from tropical cyclones, which deliver about 32% of the suspended sediment load reaching the delta, is decreasing as cyclone tracks shift north (*4*).

The remaining sediment load is further reduced by in-channel mining. An estimated 54 Mt of sand per year from the Mekong River, mostly in Cambodia and Vietnam, is used in construction and land reclamation (*5*). Sand mining causes downstream sediment starvation and contributes to coastal erosion and channel incision, tidal amplification, and salinity intrusion (*6*).

Management of the delta has historically focused on controlling the waters to enable agricultural intensification and flood regulation, and to prevent saline water intrusion. Although successful in this regard, this has fundamentally affected natural processes that maintain the delta land itself. Where distributary channels and coastal currents formerly distributed sediment-laden flood flows across the delta plain and along its coastlines, dikes now restrict water and sediment to the main channels, depriving the delta of deposition during floods. Natural mangrove vegetation traps sediment to build up land, absorbs wave energy, and reduces coastal erosion. However, the delta's mangroves largely have been replaced by agriculture and aquaculture, and remaining mangroves are now starved of sediment to trap (*7*).

All deltas naturally subside, as recently deposited sediment compacts. For the Mekong Delta, this natural subsidence is exacerbated by effects of groundwater pumping for agriculture and urban use, presently the single greatest driver of subsidence in the delta (*8*). By 2100, a "business as usual" scenario results in average relative subsidence of up to 1.8 m, which would lead to submergence of over 90% of the delta. A best-case scenario (strongly curtailed pumping, mining, and dam construction) results in subsidence of 0.15 m, which would inundate about 10% of the delta (*1*).

The above-mentioned drivers can create vicious cycles. For example, as salt water intrudes into the delta, farmers may use more groundwater, or migrate to urban centers that are already foci of subsidence. As subsidence accelerates, building dikes to lock out floods becomes more attractive to local interests, but these dikes prevent sediment from spreading over the delta surface and building elevation.

ADDRESSING ROOT CAUSES OF SUBSIDENCE

The very existence of the Mekong Delta as we know it today is due to massive human-made modifications—canals, dikes, saltwater dams, and other hydraulic interventions—that have led to major ecological and economic transformations (*9, 10*). Since the Vietnamese reunification in 1975, the delta has seen a number of studies and master plans, most with international support, to promote centralized, integrated planning with focus on socioeconomic development (*11*). Though highly successful in turning the delta into an agricultural and economic powerhouse, this has increasingly locked the delta's management into an unsustainable path with weak adaptation capacity, siloed governance, and lack of coordination with actions in upstream countries.

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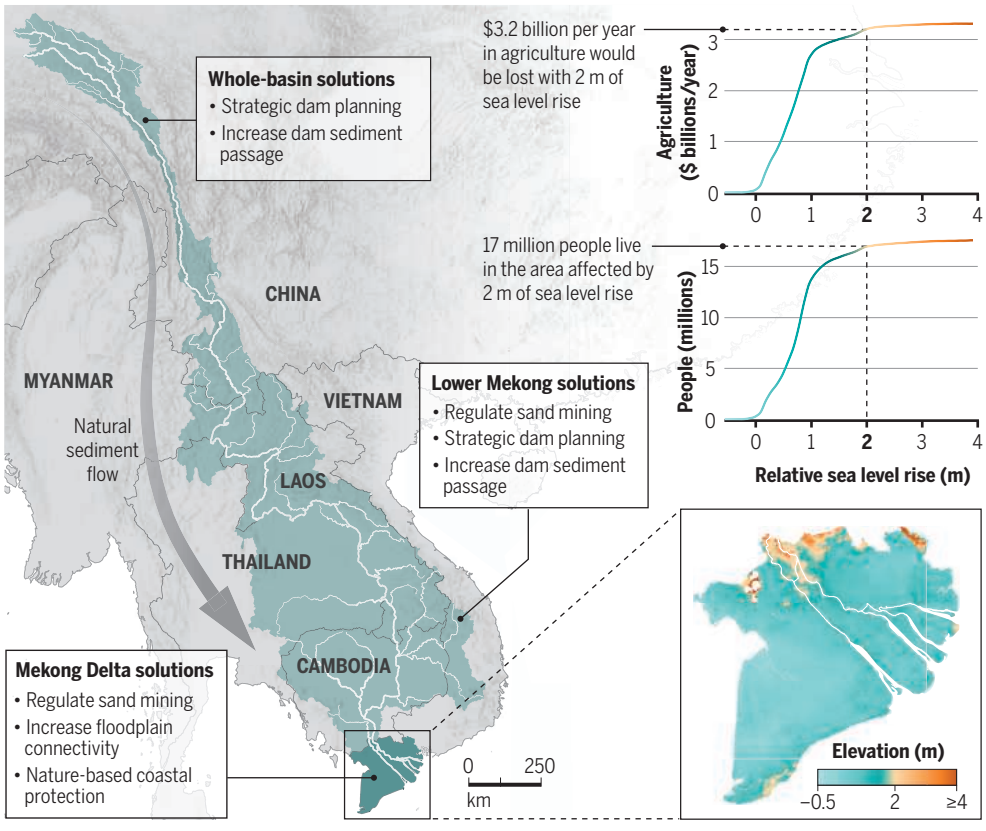
The focus on socioeconomic development and strong belief in human mastery over nature also explains why current policies fail to properly acknowledge that most of the delta might fall below mean sea level within a human lifetime. The key Vietnam government document guiding the delta's development, Resolution 120 (enacted in 2017), takes steps in the right direction, emphasizing the need for more nature-based development and encouraging integrated planning across different sectors and spatial scales, and aiming to "develop an integrated plan for sustainable and climate resilient development of the Mekong Delta" (*12*). Yet, the Resolution and the earlier "Mekong Delta Plan" (*13*) treat flooding, salinity, and coastal erosion more as isolated engineering challenges, proposing solutions on local scales, rather than explicitly seeing them as symptoms of underlying causes spanning multiple scales. Although the Plan reports ongoing subsidence rates, the existential threat to the delta is not addressed by the limited proposals to minimize subsidence, reestablish sediment connectivity, and increase delta resilience. This gap in management is also not overcome in more recent plans, such as "The Mekong Delta Integrated Regional Plan" proposed to the Vietnamese Ministry of Planning and Investment in July 2020 or the government report reviewing the first 3 years of the implementation of Resolution 120 (*14*).

At the same time, large-scale investments keep on pouring into the delta, with a mixture of instruments to advance development and respond to the threat posed by climate change. For example, the World Bank has committed to loans and bilateral funding of nearly US$2 billion from 2007 to 2022. Although this level of funding is small compared to private investment, funding decisions of international financial institutions have tremendous influence in setting standards for other investors and could help push investments that make the delta more resilient. Reputational risks are an increasingly important motivator for private investors, who are influenced by the examples set by major international actors. Much of the funding from international donors aims to address the impacts that a sinking delta creates on the livelihoods of its inhabitants: to protect against local flooding and coastal erosion, deal with salinized water supplies, and support adaptation planning. However, the investment proposals typically say little or nothing about the long-term existential risks to both livelihoods and investments, nor about opportunities to mitigate those trends through concerted larger-scale actions.

The drowning Mekong Delta

The existence of the Mekong Delta is threatened by anthropic drivers. Continuing unsustainable use of water and sediment will result in the delta surface dropping by up to 2 m relative to sea level by 2100, drowning most livelihoods and ecosystems in the delta. Measures to avoid this fate are known but need to be implemented urgently across scales, sectors, and borders (see supplementary methods for data sources).



GRAPHIC: K. FRANKLIN/*SCIENCE*

RESPONDING TO THE THREATS

Persistent challenges from top-down, hierarchical governance systems and institutional rivalries hinder continued positive evolution. For the delta landform to persist into the future, three fundamental changes in the political economy and science-society-policy nexus are required to enable six deep changes in basin management, with particular attention to sediment.

First, investments in the delta across key economic sectors (agriculture, aquaculture, transport, energy, construction) and actors (national and international companies, state-owned enterprises, local and national governments, and international development actors) need to register and address system-scale consequences of their investments, such as their impact on delta subsidence. This would require improved planning mechanisms, based on enforced regulatory frameworks. Second, actors such as civil society groups and regional and international investors with an interest in sustainable and long-term profitable investments must leverage their shared interest in making basin-scale change. For example, they can highlight that avoiding high-impact dams will benefit not only local communities but also the delta and entire basin. Third, science–policy interaction must be enhanced. One problem in Mekong basin science has been that minor differences among scientific studies have been emphasized. This gives the impression of great uncertainty in scientific predictions, but in reality, there is broad scientific consensus on key concerns. These should be emphasized when scientists communicate with decision-makers. Decision-makers, in exchange, should not take remaining differences in scientific findings as an excuse for inaction.

To respond to the fundamental threat facing the delta, future projects should not contribute to increased subsidence and land loss, and they should be resilient to future subsidence. To achieve this, we recommend that future measures explicitly account for the scales at which the drivers operate, and that management efforts be undertaken at appropriate scales. Although some drivers of subsidence can be influenced by local and national actions, others will require interventions coordinated between Cambodia and

Vietnam, and throughout the entire basin, from which the essential water and sediment resources are derived.

Coordinated planning on larger scales might seem unlikely given current political realities and persistent governance challenges. Changing those realities toward a whole-basin dialogue is needed to open a larger solution space where all riparian countries acknowledge the situation and have both rights and obligations. Here, active science–policy interaction, including the role of knowledge intermediaries such as regional networks and civil society organizations (*2*, *10*, *15*), plays an important role. Scientific understanding of the existential threats facing the delta is clear, and this understanding must be actively translated into policy recommendations. Translating such recommendations into impactful decisions requires political will and coordinated actions, both at national and basin scales. This requires accepting that some critical activities, such as overpumping, sand mining, and hydropower development, may need to be limited or gradually phased out, despite their political importance and economic interests.

In this context, we propose six measures to safeguard the delta and its livelihoods. We identify potential enablers and roadblocks to implementation (table S1). The measures will be most effective in concert, and implementing the full portfolio will be a challenge. Yet each measure has precedents (table S1).

Avoid high-impact dams

Do not build dams at sites with the highest sediment-trapping potential. Use network-scale portfolio analysis to identify optimal dam placement to minimize impacts while maintaining hydropower production. The benefits and impacts of alternative energy sources should be considered along with hydropower.

Pass sediment through or around dams

Sustainable sediment management strategies such as sluicing, flushing, and bypasses can allow some sediment to move from upstream to downstream, as included in the mainstem dam design guidance of the Mekong River Commission (MRC). Studies are needed to evaluate if dams currently not equipped for sediment management can be retrofitted.

Phase out riverbed sand mining

Impacts of sand mining can be reduced through better enforcement of mining regulations, limiting extraction to a sustainable fraction of remaining sediment load, and encouraging alternative material for construction, e.g., from floodplains and recycled material.

Transform agriculture in the delta

Produce less quantity but higher quality, and adapt agricultural practices to minimize groundwater extraction and reconnect distributaries to the delta plain. As recommended by the Vietnam Government Resolution 120 (*12*), reduce groundwater pumping through a shift to less–water-intensive crops, improve access to surface water supplies and maintain their quality, regulate water demand, and reuse water.

Maintain connectivity of delta floodplains

Adapt water infrastructure in the delta to allow sediment-charged flows to spread over the delta surface at least one year in three, and acknowledge the socioeconomic benefits of floods and sediment. Prevent dikes from cutting off channels from floodplains.

Leverage nature-based coastal protection

At low cost, mangroves and natural wetlands are a proven solution to coastal erosion with benefits for biodiversity and livelihoods, but for those ecosystems to build land there must be a supply of sediment for them to trap.

SEVERE, URGENT, EXISTENTIAL

By virtue of its national, regional, and global importance, the Mekong Delta has attracted extensive interest from the Vietnamese government, international development partners, multinational corporations, researchers, and civil society (*2*, *10*, *15*). Yet the severity and urgency of the existential threat—that most of the delta will sink below sea level by 2100—have not been explicitly mainstreamed in key policies and investment plans. The six proposed measures will entail major costs and will require coordination between civil, business, and political actors to navigate trade-offs between sectors at national and regional scales.

The proposed six-measure portfolio will not be easy to implement, but above we outline some enablers that will be crucial in the basin's governance, private sector, academia, and civil society. In the delta, national and provincial governments could act now to develop and enforce regulations for sustainable groundwater management and invest in their implementation.

In the basin, existing transboundary organizations must play a key role. Although the MRC is unlikely to gain binding power to make strategic development decisions, it needs to strengthen its role as knowledge broker and amplifier of transboundary environmental issues (*15*), including demonstrating that cooperation yields greater benefits than unilateral action. As more investments will pour into the basin, e.g., with the intensification of ASEAN (Association of Southeast Asian Nations) power trade, such information will be crucial to hold private and government investors accountable for the externalities of their investments.

Organizations with active transboundary and trans-sectoral investment portfolios, e.g., multilateral development banks such as the World Bank and Asian Development Bank, are already positioned to evaluate the systemic impacts of investments rather than focusing only on project-level sustainability assessments (*10*). Because of the high visibility of multilateral development banks and other international organizations, their commitment to strategic and systemic solutions can further awareness among national actors, and they are well positioned to support sectoral reforms and highlight the role of strategic assessments and sustainable use of riverine resources.

All those organizations and actors need to broaden their scope from a narrow focus on developing the basin's water and energy resources (*10*) to consider additional sectors (e.g., construction, food) and holistic solutions to address root causes of a subsiding delta. Implementing those solutions could make the Mekong Delta a sentinel of integrative and innovative delta management and climate adaptation, rather than being drowned by the century's end. ■

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