Sustainable rice cultivation in the deep flooded zones of the Vietnamese Mekong Delta

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Abstract:

This paper explains how the management of the full-dyke system in the deep flooded zones of the Vietnamese Mekong Delta affects rice cultivation, and outlines how alternative dyke management strategies could offer more sustainable adaptations in the face of future environmental threats. The current management of the 'full-dyke' network has been successful in promoting triple-cropping rice cultivation, but this practice has prevented sediment deposition on the land surface. River-borne sediments deposited on the delta land surface have high economic value because they are (i) rich in nutrients (potentially 26 million USD/yr of free fertiliser to An Giang Province) and can (ii) help to maintain the Mekong Delta land above sea-level. Without a continuing supply of sediment to the delta, triple-cropping paddies may not continue to be sustainable or profitable for the majority of rice farmers over the next 10 to 20 years. The economic value of sediment as a free fertiliser is particularly important to poor farmers, as without sediment, they run a significant risk of debt due to fluctuations in rice, fertiliser, and other input prices. With incoming loads now declining, sediment must be managed carefully as a resource. Our projections show that the best use of the remaining sediment resource can be achieved by allowing full paddy flooding only in years of high sediment potential, and this would greatly increase the sustainability of rice agriculture in the face of future environmental change. This recommended policy is an option with few regrets, in that its other benefits include maximising groundwater replenishment, ensuring freshwater availability during drought periods (including countering salt water intrusion), cleansing rice paddies of pests and disease, and tempering downstream flooding. If triple-rice-cropping continues to have priority, financial support will particularly be needed to provide help to poorer farmers coping with increases in artificial fertiliser prices.

Keywords: *deep flooded, dyke, Mekong Delta, rice, rice cultivation, sediment, sustainability.*

Classification number: *3.1*

Introduction

The Vietnamese Mekong Delta (VMD), one of the most productive agricultural regions on Earth, is vital to global food security, the Vietnamese economy, and sustaining the livelihoods of its 18 million residents [1]. The VMD is vulnerable to environmental changes, such as with the size and timing of floods and droughts, sea-level rise, and salt-water intrusion, which come as a result of climate change and human modifications to the Mekong River's basin upstream [2]. These environmental changes, combined with local development pressures, represent significant threats to the Delta, such that the VMD is now facing a major sustainability challenge [3]. Among the most serious of the expected impacts is the ongoing decline of the Mekong River's sediment load. Our work has shown that in the last 30 years, there have been substantial declines in sediment load as a result of climate change and extraction of sand from the river bed [4]. We, and other scientists, also project this decline to continue in the future, by between 50-90% over the next 20-30 years, due to a combination of ongoing climate change and trapping behind upstream dams [4, 5]. However, at present a significant sediment resource is still available (Hung et al. estimate 6.83 kg/m^2/year) [6]. The deposition of nutrient-rich sediments is important both in replenishing agricultural soils and building land height across the Delta, but it is especially significant in the 'deep flooded zones' in the north (Fig. 1).

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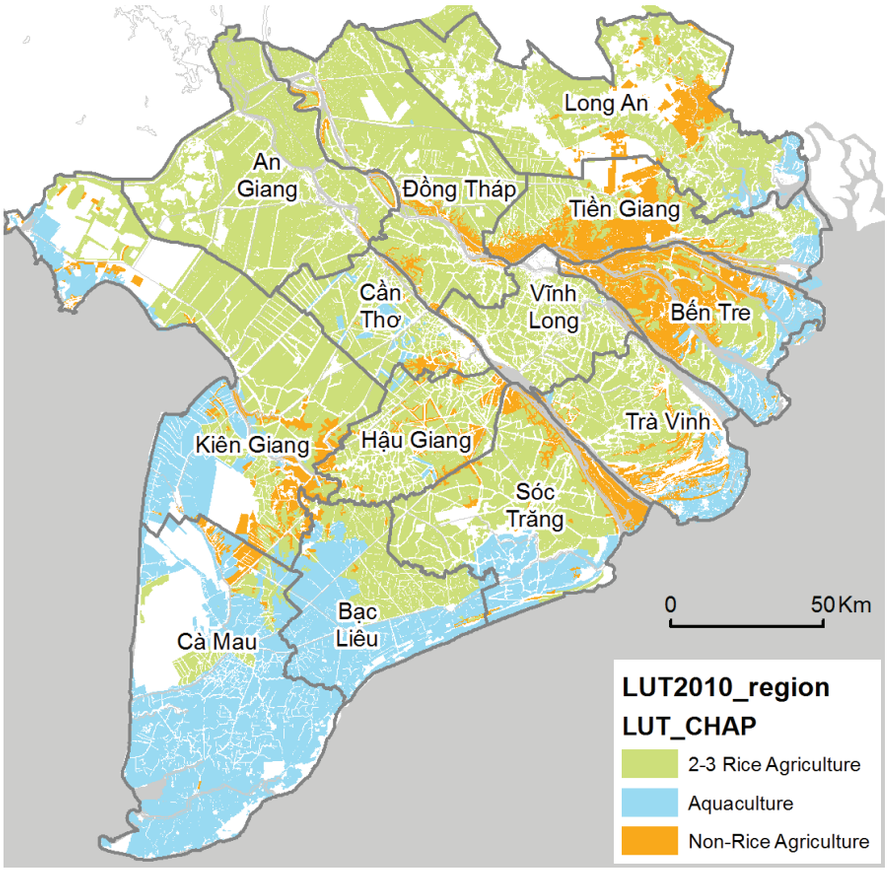

Fig. 1. Map and agro-ecological zones of the Vietnamese Mekong Delta.

Methods

Data collection

Strategic decisions on the VMD's hydraulic operations are guided by targets set at the national level, but specific decisions on the system's management are made and controlled at the provincial level of governance. We conducted a semi-structured focus group with four high-ranking provincial officials to clarify the context within which decisions on hydraulic operations are made.

Our objective was to examine the impacts of high dykes, triple-cropping, and sediment exclusion from a socioeconomic perspective. Floodplain sedimentation can be highly spatially and temporally variable and hence difficult to measure; data is sparsely available on local rates in the VMD. However, farmers of the VMD are aware of the fertilising effects of fluvial sediment, and most typically work any sediment left by inundation into an even spread around their paddies. While previous research has shown that perceptions may differ from physical measurements, the strong local knowledge of this phenomenon meant that we posited that farmer perceptions could provide a meaningful estimation. Asking farmers to make quantitative estimates of the depth of the sediment (if any) left behind by the monsoon was a new approach to analysing the deltaic environment. To help this process, farmers were presented with visual aids (a scale showing different depths, and a diagram). Some simple validation checks of the farmers' reported sediment values and greater detail on the data collection and analysis can be found in the supplementary information.

Framework

The cause and effect relationship framework are used to structure our methods, analysis, and discussion. The method is a simple framing tool, pioneered by the OECD [7]. The framework encourages the presentation of a problem's cause and impacts in a format that is clear and easily translated into policy. Studies used the expert approach, Participatory Rural Appraisal (PRA), and local staff consultation. Data analysis used regression models and calculations of the economic value of the sediment.

Results and discussions

Threats to the Vietnamese Mekong Delta

The deep flooded zone is home to around a third of the Delta's population, and is the most intensive rice-growing region in Vietnam. In the deep flooded zones, and particularly in An Giang Province, an extensive network of high dykes (the 'full-dyke' system, see Abbreviations) has proven very effective in regulating and controlling the annual flood, leading to favourable conditions for intensive rice agriculture, with yields improving on average by around 2-3% year-on-year since 2000 [8]. This yield growth has largely been achieved by introducing triple-cropping to new areas. However, just as they are barriers to flood waters, full-dykes also exclude sediment from rice growing compartments. As a result of this, the deep flooded zones now face the multiple challenges of a sinking floodplain, declining soil fertility, and increasing agricultural input costs at a time when a sediment resource is still available.

Stakeholders (Fig. 2) have highlighted both the potentially positive and negative impacts of the 'full-dyke' system. It is clear that the local stakeholders (provincial and district officials, especially those from Department of Agricultural and Rural Development (DARD) and Department of Natural Resources and Environment (DONRE), as well as members of the Farmers Union) [9] value the positive socioeconomic impacts derived from the way in which the full-dyke system is currently managed; albeit stakeholders also have concerns about valuable environmental resources being degraded. Despite these concerns, MARD made new commitments to large-scale expansion

of triple-rice-cropping and supporting infrastructure as recently as 2015, with the deep flooded zones to take the largest share (Decision No. 101/QD-BNN-TT). Our research provides an early warning that livelihoods, which depend to a large extent on the natural resources excluded by triple-cropping, face long-term threats from declining productivity, inequality, and the sinking of the Delta below sea-level. Our work, therefore, challenges some of the assumptions made by local stakeholders and decision makers, but also identifies potential and attainable adaptations that could help to protect natural capital in the VMD for future generations.

Focus on key sediment-related impacts of the current system

Our research challenges some of the assumptions (Fig. 2) made by local stakeholders about the full-dyke system, and highlights how triple-rice-cropping inside the full-dyke rings threatens the ability to meet policy objectives set out by the national and provincial authorities. Specifically, we have shown that the consequence of a full-dyke system is to reduce the depth of nutrient-rich sediment deposited on rice paddies by a factor of five [10].

The socio-economic implications of this decline are serious. Our data highlights the high short-term costs caused by the loss of the fertilising nutrients within the deposited sediments. We estimate sediment is currently providing around 11 million USD/yr of free fertiliser in An Giang Province's remaining flooded areas, and that is around 15 million USD/yr which is being excluded and lost due to the full-dyke system. This figure is less than the gross profit (c. 80-150 million USD/yr) currently being derived from the third rice crop, but the loss of free fertilisation is critical to the economic wellbeing of poorer farmers and is, therefore, in tension with the government's objectives that target greater equality, poverty alleviation, and sustainability in the delta. Moreover, additional long-term costs (due to damages incurred by rising sea-levels as a result of the reduced natural rate of land building) associated with the exclusion of sediment from paddy compartments are not currently considered in cost-benefit analyses of the triple-cropping policy.

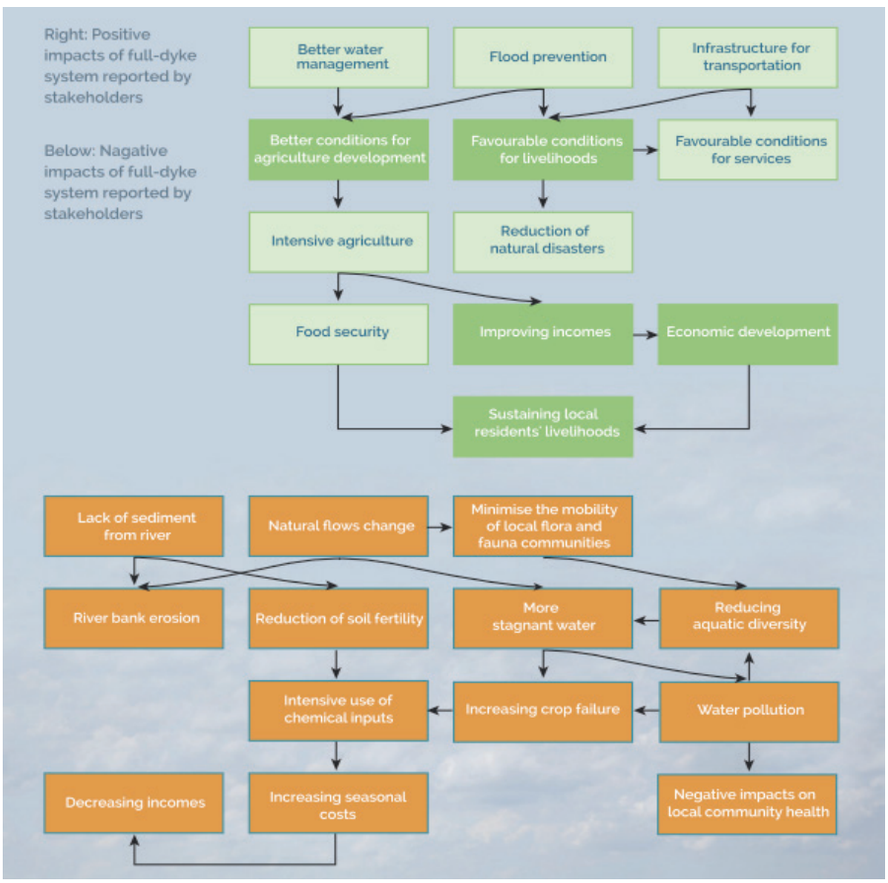

Fig. 2. Focus group output comprising reported positive and negative impacts of the full-dyke system.

Farmer concerns:

- Free fertilisation from nutrient-rich sediment is of particular value to poorer farmers. On average, natural sediment delivered from floods improves agricultural efficiency by 2% and increases the annual profits of an average size paddy by around $190 per year. The benefit of this free input is critical to poor farmers who operate within narrow profit margins; without it, their vulnerability to volatility in fertiliser price increases. Our data suggests approximately 48% of farmers are operating paddies of 1.5 ha or less in size (and 32% below 1 ha) while only 12% operate what we consider to be 'large' paddies (greater than 5 ha).

- Triple-cropping increases inequality and debt in poorer households. Triple-cropping places a much higher reliance on artificial fertilisation. Our work shows that after around 10-15 years of triple-cropping, farmers apply almost twice as much fertiliser per year as they do under double-cropping [11]. Poorer farmers who lack the technical capacity to apply fertiliser efficiently incur higher costs and an intense workload.

Government concerns:

- Sediment deposition is the only way to offset the sinking of the delta region into the sea. The most recent research shows that the deep-flooded zones of the Delta are sinking at around 1cm per year due to natural processes and subsidence linked to groundwater extraction [12]. Without sediment to raise the ground-level, the economic costs of infrastructure development to prevent land loss will grow and the viability of livelihoods in the long-term future will be threatened. While sediment loads are declining, full-

dykes are excluding sediment from paddy compartments at a time when considerable sediment resource still remains available.

- Our projections (Fig. 3) show that high productivity levels currently associated with triple-cropping are not sustainable in the long-term. Triple-cropping depletes the nutrient buffer provided by sediment [13]. In the future, the total annual yield per hectare inside the full-dykes will fall lower than that which could be achievable inside low dyke rings (also termed August dyke rings) which allow monsoon season inundation. This decline represents a long-term threat to government revenues from export taxes.

- The triple-cropping system increases the vulnerability of farmers to debt and contributes to social issues. As a growing number of poor farmers are forced to sell their land to pay debts, unemployment and migration levels will grow. There is already evidence of net migration out of the deep-flooded zones of the delta at far higher rates than other delta provinces and indeed other provinces around Vietnam. The current high rates of net migration will be a result of multiple factors, but the triple-cropping strategy is also a contributing factor.

The impacts of different dyke management policy options

Our model projections compared outcomes from a range of alternative cropping policies against the current dominant strategy of uninterrupted triple-cropping [10]. These alternate policies (Fig. 4) represent potential adaptations of current practice in response to different future scenarios of sediment decline.

Double-cropping inside full-dyke systems with paddy inundation annually through sluice gate operation: Over the short-term (5-10 years), this adaptation provides farmers access to natural free-sediment bound nutrients and allows farmers to seek alternative sources of income during the wet season, offering farmers greater resilience to economic shocks. However, the effectiveness of this policy over the long-term is threatened by the construction of multiple hydropower dams upstream in the Mekong Basin, which may significantly reduce the overall supply of sediment. In addition, flooding paddies only through sluice gates may reduce the quantity of sediment reaching the floodplain when compared with traditional flooding via dyke-overflow.

The 3-3-2 cropping rotation: This policy (recommended by An Giang Provincial Government) marginally increases average sediment deposition, but our evidence shows that it does not significantly improve socio-economic outcomes. Challenges, particularly with debt, are presented when sluice gates are opened in low-flood years that only achieve low sediment deposition.

Opening of sluice gates in years of high sediment potential: This adaptation allows floods with high sediment potential to be released onto paddies to ensure maximum sediment deposition is achieved during breaks from rice-cropping, and also has the benefit of reducing flooding intensity in downstream regions. Effective implementation of this policy relies on accurate information about the conditions of the Mekong River upstream and effective communication with all levels of agricultural administration to ensure farmers are warned in advance that flooding of the dyke rings will take place. As flood predictions are imperfect, there may be instances where flooding disrupts farmers who began sowing their fields with rice-. In these cases, steps will need to be taken to support farmers, and information and training may need to be disseminated to minimise risks and costs.

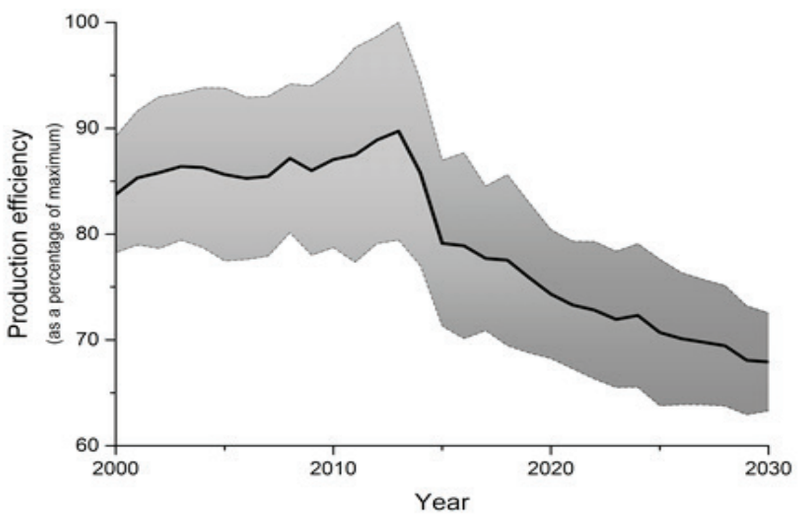

Fig. 3. Model projections of agricultural input efficiency (yield achieved against fertiliser applied) between 2000-2030 assuming the continuation of uninterrupted triple-cropping.

Conclusions and recommendations

Support to farmers

Our projections suggest that any policy which involves triple-cropping will need to be supported by the provision of greater and increasing financial assistance to farmers, especially the poorest farmers. Productivity levels are rapidly declining, fertiliser prices are rising, and the need to fertilise crops to maintain yields is rising. Opening sluice gates to allow sediment deposition and flooding to take place, may, on average, be advantageous to the majority of farmers; however, due to the unpredictable nature of floods, farmers may suffer economic losses during the period when sluice gates are opened and rice cultivation is stopped. As such, we recommend local governments to identify ways to assist farmers financially, both during the period of flooding and also in the early weeks of the following season. Our model suggests an effective mechanism

for assisting farmers is to subsidise, or guarantee farmers a fertiliser or rice price. This gives farmers greater income security during an uncertain period. The quantity of financial assistance required might be reduced through greater and wider provision of training to improve farmers' technical capacities to apply inputs.

scenarios.

Mechanisms for providing financial support to the poorest farmers when sluice gates are opened and when fertiliser prices are high (or rice prices low) should be implemented.

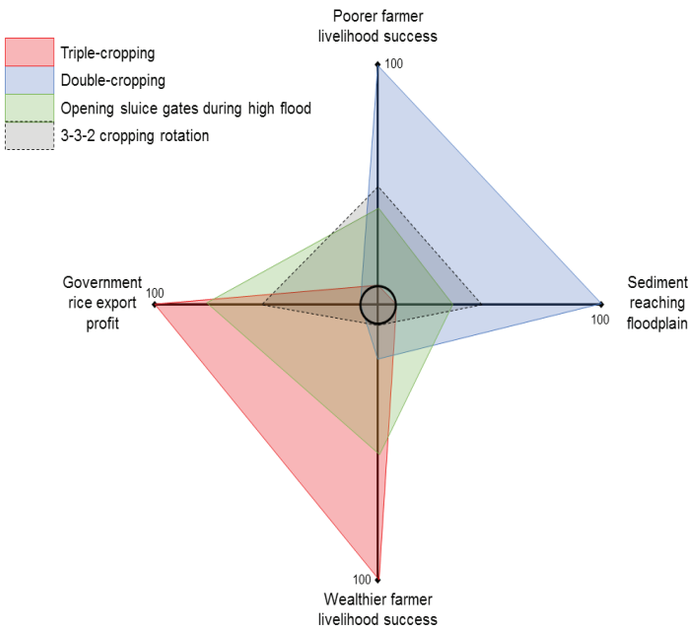

Fig. 4. Model projected trade-offs between four policies, showing relative outcomes against four indicators.

Recommendations for provincial dyke and agricultural management

Our projections suggest that option 3 (opening sluice gates during years of high sediment potential) represents the strongest middle-ground between different stakeholders' interests and environmental services, and for achieving long-term sustainability.

Careful planning, with reference to the most up-to-date research [8] is required alongside any of the three policies described above, to ensure sluice gate operation encourages maximum sediment deposition.

We believe that investment into improving the agricultural input practices of the poorest farmers would be an effective complement to all of our tested

In Fig. 4, policy outcomes are defined on a normalised comparative scale, and are based on a mid-range estimate of sediment decline (51% decline over the next 20 years). For further information on methods behind this figure, please refer to Chapman and Darby (2016) and further details are available in Chapman (2016) [14].

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