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BARRIERS TO IMPLEMENTING IRRIGATION AND DRAINAGE POLICIES IN AN GIANG PROVINCE, MEKONG DELTA, VIETNAM†

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ABSTRACT

Water management in delta floodplains worldwide faces many challenges due to the changing climate and increasing human intervention in the hydrological regimes of rivers. Irrigation and drainage systems are necessary components of a water management strategy that aims to support human habitation and agricultural production, but which need effective coordination in order to adapt to exogenous impacts. However, management of such systems often fails for a variety of reasons. In the floodplain of the Vietnamese Mekong Delta, irrigation and drainage systems under dike protection confront ineffective implementation of water management policy, posing a challenge for adaptation to exogenous impacts on the hydrological regime. Over the past two decades, farmers have increasingly cultivated annual triple-rice crops in high-dike compartments, ignoring government regulations that call for flood retention. This study analyses interviews with farmers to identify their motivation for not implementing the triennial cropping off-season advised by the local government (3–3–2 cycle). Our findings show that farmers have avoided implementing the 3–3–2 cycle because of various disadvantages that the system presents for them. Local officials, in turn, have accepted farmers' disregard of the rule. Lessons learnt from this study are considered to explore measures to effectively adapt to future hydrological changes. © 2017 The Authors. *Irrigation and Drainage* published by John Wiley & Sons Ltd on behalf of International Commission for Irrigation and Drainage

KEY WORDS: irrigation and drainage; dike protection; floodplain; livelihoods; Mekong Delta

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RÉSUMÉ

La gestion de l'eau dans les plaines d'inondation des deltas du monde entier pose de nombreux défis en raison de l'évolution du climat et de l'augmentation de l'intervention humaine dans les régimes hydrologiques des cours d'eau. Les systèmes d'irrigation et de drainage sont des composantes nécessaires d'une stratégie de gestion de l'eau qui vise à protéger l'habitat humain et la production agricole, mais qui nécessitent une coordination efficace pour s'adapter aux impacts exogènes. Cependant, la gestion de ces systèmes échoue souvent pour diverses raisons. Dans la plaine d'inondation du Delta du Mékong vietnamien, les systèmes d'irrigation et de drainage sous la protection des digues font face à une mise en œuvre inefficace de la politique de gestion de l'eau, ce qui pose un défi pour l'adaptation aux impacts exogènes sur le régime hydrologique. Au cours des deux dernières décennies, les agriculteurs ont de plus en plus adopté des systèmes d'exploitation basés sur trois cultures de riz/an dans les compartiments topographiquement plus élevés, en ignorant les réglementations gouvernementales qui exigent la rétention des crues. Cette étude analyse les entretiens avec les agriculteurs pour identifier leurs motivations à pas mettre en œuvre la cycle triennal hors saison conseillée par le gouvernement local (cycle 3–3–2). Nos résultats montrent que les agriculteurs ont évité de mettre en œuvre le cycle 3–3–2 en raison de divers inconvénients que le système présente pour eux. Les fonctionnaires locaux, en retour, ont accepté le mépris des agriculteurs à l'égard de la règle. Les leçons tirées de cette étude sont considérées comme des mesures exploratoires pour s'adapter efficacement aux futurs changements hydrologiques. © 2017 The Authors. *Irrigation and Drainage* published by John Wiley & Sons Ltd on behalf of International Commission for Irrigation and Drainage

MOTS CLÉS: irrigation et drainage; protection des digues; plaine d'inondation; moyens de subsistance; Delta du Mékong

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†Les obstacles à la mise en oeuvre des politiques d'irrigation et de drainage dans la province d'An Giang (Delta du Mékong, Vietnam).

INTRODUCTION

The agriculturally productive Vietnamese Mekong Delta (VMD) is highly vulnerable to the effects of climate change and human structural interventions. Changes in flood magnitudes due to a changing climate, local flood-protection infrastructures for agricultural production, and upstream irrigation and hydropower developments have caused unusual water regimes in the delta in recent years (Lu and Siew, 2006; Fredrik, 2011; Pearse-Smith, 2012; Birkmann *et al*., 2012; Kuenzer *et al*., 2013; Richard and Tran, 2014; Hoang *et al*., 2016; Piman *et al*., 2016; Hanington *et al*., 2017). The United Nations Disaster Risk Management Team (2016) indicated that the average water level in the lower Mekong River in 2015 was the lowest it had been in nearly 100 years. Data provided by the Mekong River Commission showed the lowest floodwater hydrographs recorded at Tan Chau from 2015 to 2016 compared to the six previous years (Figure 1). While a rare extreme, this coincides with the beginning of the full operation of six hydropower dams in China in 2015 (Konishi, 2011), in combination with a severe El Niño, which may have been made worse by climate change (Sothea, 2016). In addition, sediment loads have significantly decreased in the rivers and floodplains of the Mekong Delta due to the above-mentioned activities (Lu and Siew, 2006; Kummu and Varis, 2007; Fredrik, 2011; Hung, 2012; Lu *et al*., 2014; Manh *et al*., 2014; Pearse-Smith, 2012; Hung *et al*., 2014a). These changes raise the need for an irrigation and drainage strategy that will help promote successful and sustainable livelihoods for farmers in the floodplains of the VMD.

The rapid changes in flood protection strategies from no-dike and semi-dike to high-dike for intensive rice-based agricultural activities have exacerbated water connection issues between rivers and irrigation canals, causing changes in natural hydrological regimes and associated environmental problems (Käkönen, 2008; Howie, 2011; Huu, 2011; Garschagen *et al*., 2011; Southern Institute for Water Resources Research (SIWRR), 2012; Kingdom of the Netherlands and the Socialist Republic of Vietnam, 2013). At the farm scale in the floodplain, large-scale high dikes were constructed after a particularly severe flood in 2000, especially in An Giang Province, to protect against flooding and ensure three crops of rice per year. However, intensive agricultural production required the heavy use of fertilizers and pesticides, which significantly degraded the land and soil quality (Howie, 2011; Kien, 2014; Dan, 2015). Typically, annual floodwaters would flush these agrochemical toxins from the soil and deposit fertile sediments, but high dikes prevented the floodwaters from entering the fields for such natural soil-quality enhancements (Hung, 2012; Hung *et al*., 2014a; Manh *et al*., 2014). High dikes also decreased the flood retention capacity of the Long Xuyen Quadrangle, one of two flood storage areas in the upper part of the VMD, thereby increasing flood risks downstream (Kingdom of the Netherlands and the Socialist Republic of Vietnam, 2013; Marchand *et al*., 2014). Given these developments, a proper water management strategy at large scale, and systems for irrigation and drainage at farm scale, are needed to help improve the sustainability of farmer livelihoods. A strategy that attempts to maximize floodwater retention, maintaining the storage capacity of the floodplain, will also help to enhance the agricultural resilience of the delta as a whole (Nhan *et al*., 2007).

Irrigation and drainage systems in the floodplains of tidal river deltas typically include pumps, canals, and dikes or polders (Lukianas *et al*., 2006; Ritzema, 2013). In the floodplain of the VMD, irrigation and drainage systems

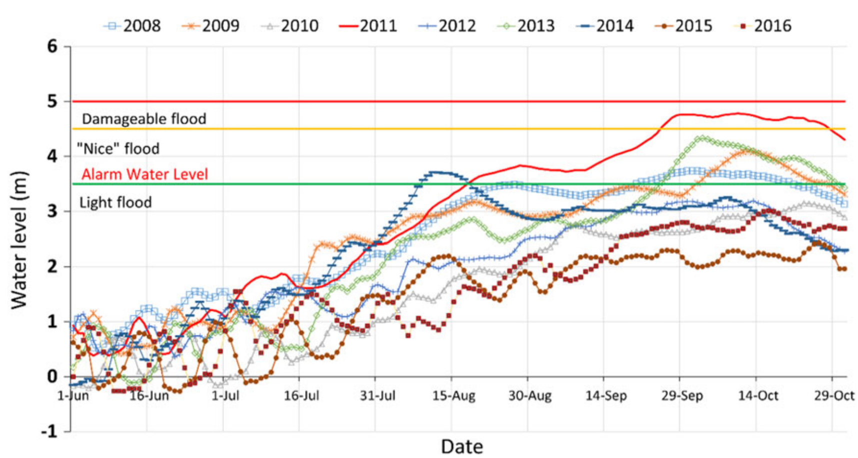

Figure 1. Changes in flood hydrographs of water levels measured at Tan Chau in the period 2008–2016. Light flood: water levels at Tan Chau <3.5 m. > = 3.5 m: alarm water level. 'Nice flood': water level at Tan Chau in the interval of 3.5–4.5 m. Damageable flood: water level at Tan Chau >4.5 m. In 2015 and 2016, water levels were smaller than 2.5 m. Water levels in 2015 and 2016 are very low compared to previous years. Definition of 'nice flood', damageable flood, and light flood are referenced from Mekong River Commission (MRC). [Colour figure can be viewed at wileyonlinelibrary.com]

are most often based on private and collective pumping stations to pump water in and out of fields, which are protected against flooding by a number of low and high dikes (Figure 2). The use of pumps derives from the flat topography of the delta, which does not allow for gravity-fed irrigation based on canal delivery with sluice gates, so is not commonly applied for inland dike compartments. In low-dike compartments, farmers pump water from tertiary canals to fields to irrigate the first two crops of rice, and then floodwater is allowed to flow over the banks during the flood season (August–November). In high-dike compartments, floodwater is prevented from entering the fields and three rice crops are grown annually (Howie, 2011; Huu, 2011; SIWRR, 2012; Trung *et al*., 2013; Kien, 2014; Dan, 2015). A common irrigation and drainage system is presented in Figure 3.

To flush away toxic chemicals and increase the fertility of the soil inside high dikes, in 2007 provincial authorities established a rule of 8 crops in 3 years (3–3–2 cycle). Decision No. 76 was issued, requiring farmers to allow their rice lands to flood in the third season of the third year. This is the only existing irrigation and drainage strategy that aims to maintain controlled flood inundation and sediment deposition in the compartments protected by high dikes (Chapman *et al*., 2016). However, the rule has not been widely or effectively implemented by farmers and local authorities. In 2016, for example, Chapman *et al*., (2016) reported that only two of the nine communes they surveyed in An Giang were operating the 3–3–2 system. The other seven communes ignored the 3–3–2 system to practise triple-rice cropping inside the high dikes over many years.

Cooperation between farmers and local officials plays an important role in the successful implementation of farming-based water management for irrigation and drainage systems (Michael, 1999). Local officials are responsible for enforcing government policy to ensure a coordinated strategy for the whole area, but farmers decide whether to implement such strategies at the local (farm) level. Therefore, it is important to understand farmers' perspectives about the irrigation and drainage systems in question. In addition, poor predictions of water regimes due to climate change and upstream developments can further challenge local water management practices. In the VMD floodplain, the 3–3–2 strategy for irrigation and drainage was established by provincial authorities but has been inadequately implemented by farmers. The purpose of this paper is to identify the reasons for this disregard of the government-mandated irrigation and drainage policy in An Giang Province, and to explore alternatives for more successful water management that can increase the resilience of farmer livelihoods in the face of changing flood regimes due to climate change and upstream developments.

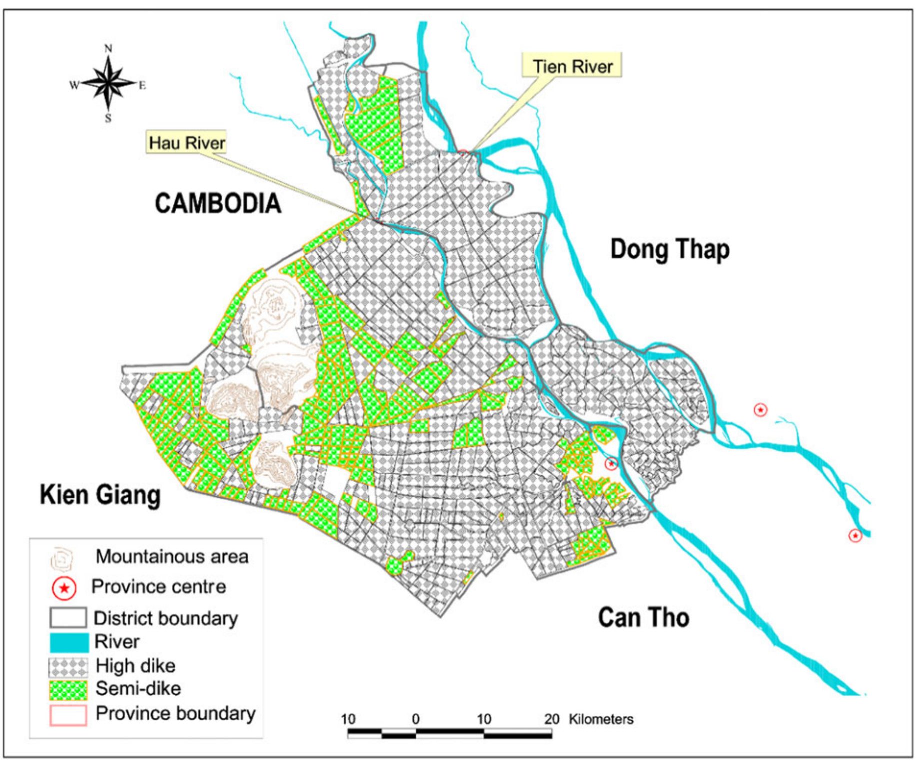

Figure 2. Existing low- and high-dike areas in 2014 (Data source: AGDARD, map by authors). [Colour figure can be viewed at wileyonlinelibrary.com]

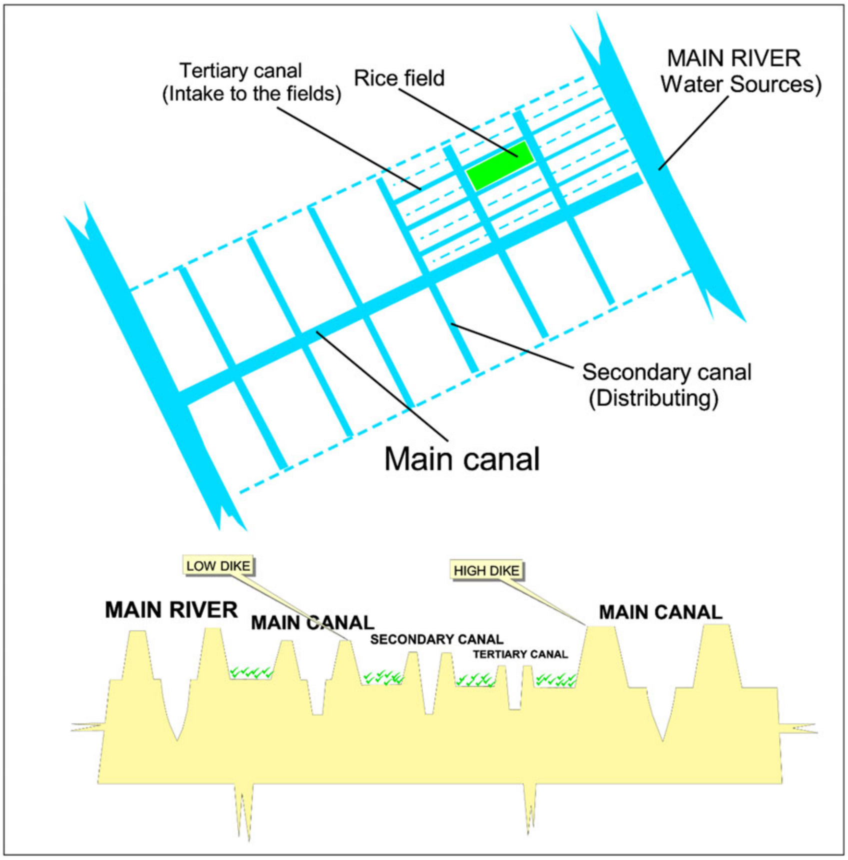

Figure 3. Common irrigation and drainage in the Vietnamese Mekong Delta (Source: authors). [Colour figure can be viewed at wileyonlinelibrary.com]

Findings from this study will be valuable to farmers, local officials, and decision-makers seeking suitable irrigation and drainage strategies for sustaining farming systems in delta floodplains worldwide, many of which face similar pressures today from a changing climate and hydropower development upstream.

In this study, we analyse the perspectives of farmers and local officials about this strategy for irrigation and drainage and explore alternatives/adaptation measures to increase farmer livelihood resilience in the floodplain of the VMD. To this end, semi-structured interviews were carried out with 60 farmers and 3 local officials mostly in An Giang Province, with a small portion carried out in Dong Thap Province, exploring their perspectives about current farming systems and barriers to implementing the 3–3–2 cycle inside high-dike compartments. In doing this, we assess the feasibility of flooding high-dike areas during the third rice season of the third year. Interview data are supplemented with primary data from a survey of 998 households in An Giang Province carried out by the Centre of Water Management and Climate Change, Vietnam National University–Ho Chi Minh City, on farmer livelihoods. A desktop review of the literature provides additional evidence to compare and integrate solutions for achieving effective and sustainable water management in the delta floodplain.

SITE DESCRIPTION

Study area and farm characteristics in An Giang Province

An Giang Province is situated in the upstream part of the VMD, between 10^0 12′–10^0 57′ N and 104^0 46′–105^0 35′ W (Figure 4). It is located in the Long Xuyen Quadrangle (LXQ), one of two floodplains in the delta, in a monsoon climate region with annual wet and dry seasons. With a total area of about 3536 km^2 and home to more than 2 million people, the province is administratively divided into 11 districts or cities, and 79% of the total area is used for agricultural production (2790 km^2). An Giang is the leading province of the VMD for rice production and is considered one of the highest rice-producing areas of the country.

In agro-ecological terms, An Giang Province can be divided into three zones: the island zone, the plain zone and the mountainous zone (Kien, 2014). The island zone (960 km^2) sits between the Tien and Hau rivers, the two

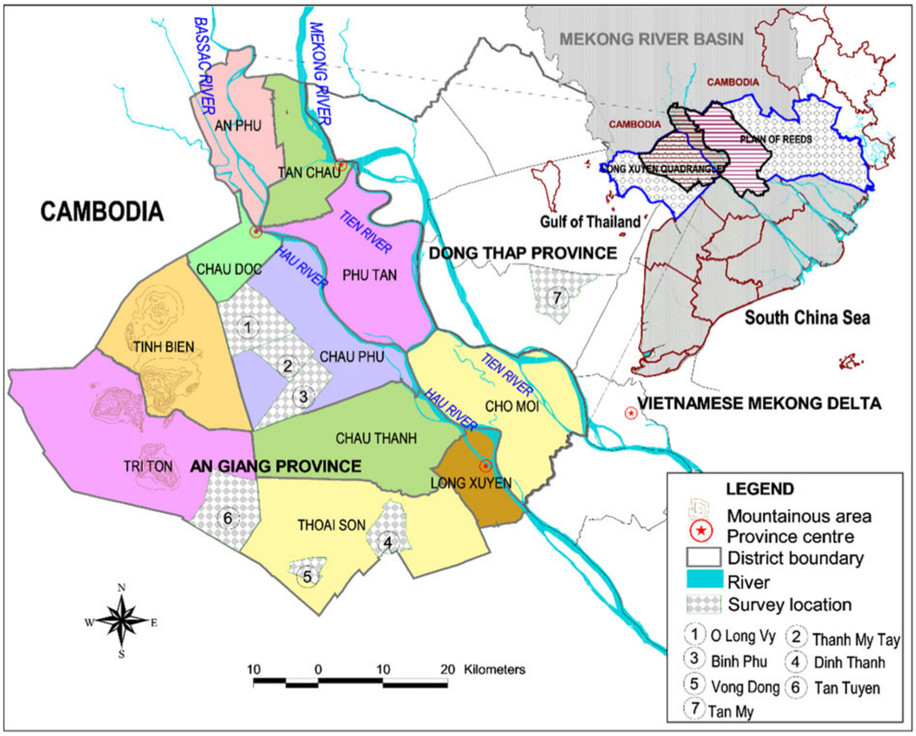

Figure 4. An Giang Province and survey locations (Source: map by authors). [Colour figure can be viewed at wileyonlinelibrary.com]

main branches of the Mekong River, and its dominant soil is alluvial. The plain zone (2000 km^2), lying south-west of the Hau River, is the largest and most flood-prone part of the province. The mountainous zone (560 km^2) is situated in the south-western corner of the province and consists of several small granite mountains. The island and plain zones are annually inundated for 2–6 months during the flood season, depending on the magnitude of floods, whereas the mountainous zone is not affected. Aside from the rocky mountainous zone, the two zones of island and plain are highly suitable for agricultural production, in large part due to the benefits such floods bring.

Floods are a common natural occurrence in the VMD. However, in addition to causing damage, every year from July to November the floods also bring to the delta common pool resources such as fertile sediment and wild fish (Howie, 2011; Käkönen, 2008). Flowing across the border with Cambodia and down the two main branches of the Mekong River, the Tien and Hau, floodwaters inundate the province, overflowing from the dense network of canals to produce a range in water depths from 0.5 to 5.5 m above mean sea level. Historically, residents did their best to take advantage of the floods for their farming systems. From a dominance of monoculture floating rice in the past, farmers eventually developed double- and triple-rice cultivation using high-yielding varieties after the 1980s. Dikes were built which created numerous compartments to protect fields against flooding for double- and triple-crop cultivation each year (Xuan and Matsui, 1998).

Water management and farming systems

An Giang Province and neighbouring Dong Thap are strongly affected by floods; therefore, the primary approach to water management is based on using dikes and related water control infrastructures to ensure the safety of people and property, as well as of agricultural activities. Specifically, investments were made in large-scale concrete core dikes, which double as main roads, as well as sluice gates, canals, and pumps to help local inhabitants maintain safer living conditions and improve their well-being. Moreover, smaller dike systems were constructed at farm scale to protect farms from inundation, ensuring the safety of agricultural production during the flood season (SIWRR, 2012). Many main dikes and farm dikes, functioning as roads, also connect farms with markets, providing additional advantages for farmers. However, these structural elements were not constructed uniformly and have become degraded over time due to lack of maintenance. Most only serve the community or at a local scale. Thus, there are many limitations to coordinated operation of the system at a larger scale, contributing to the overall ineffective water management seen in the province (SIWRR, 2012).

Farming systems in An Giang are protected by either low or high dikes (Figure 2). Low dikes (or semi-dikes) are earthen dikes, which have a typical height of 0.5–1.0 m and are constructed at locations with flood depths of over 1.5 m, allowing floodwater to flow over the top of the dikes during the flood season. High dikes are built with a concrete or asphaltic concrete road on top, at a height of 2.0–2.5 m, in places where maximum flood depths are less than 1.5 m, to completely prevent floodwater from entering the fields (SIWRR, 2012). Low dikes are used to protect double crops of rice each year in order to ensure the second crop (summer–autumn) can be harvested before floodwaters enter the fields. After the harvest, floodwaters are able to flow over the low dikes, bringing fertile sediments into the fields. In contrast, high dikes fully protect rice fields against floodwater year-round to allow for triple-rice cultivation annually. High-dike compartments are similar to closed polders in the Netherlands but smaller in size (Marinissen, 1994), where in each dike compartment, irrigation water intake and outtake are regulated by two sluice gates as needed.

In low-dike systems, farmers cultivate winter–spring and summer–autumn rice crops from December of one year until August of the following year. Every season, vegetable crops such as pumpkin, watermelon, maize, and others account for around 20% of the land area, planted in suitable higher-elevation areas (SIWRR, 2012). Fish and shrimp ponds are also common in some districts where the area is not inundated in the flood season. During the flood season from August to November, fields are inundated and it is a time mostly useful for poor and landless famers who catch wild fish and shrimp, use fish cages, and harvest different varieties of floating rice or vegetables such as water mimosa, lotus, water lily, and *Sesbania sesban*. These flood-based crops must be planted in sheltered locations that are protected against strong flood waves and wind. Although it is difficult for farmers to cultivate during the flood season, it is considered a sustainable option if farmers are to adapt to living with floods (Howie, 2011).

Inside high dikes, farming systems consist of triple crops of rice, cultivated over 12 months of the year, except for the short time needed between crops for soil preparation. Triple rice under high-dike protection currently obtains the highest percentage (91% of total agricultural area) of farming systems practised in the province (General Statistics Office of An Giang (AGGSO), 2014). Vegetable crops and fishponds account for a small proportion (9%) of land area compared to rice. The advantage of such a farming system is that farmers can not only cultivate crops year-round, but many are also able to raise poultry or cattle on dry land to increase their incomes. The disadvantage is that it causes degradation of the soil over the long run due to the loss of fertile sediment from floodwater and the accumulation of agrochemicals from intensive cultivation (Howie, 2011; SIWRR, 2012; Dan, 2015).

There are thousands of sluices in the province, which are generally classified into one of two types: either large or small sluices. Large sluices, under main roads (high dikes), are usually installed at the head of the delivering canal for water regulation (SIWRR, 2012). Typically, these sluices have gates or valves used to control water levels inside and outside the dikes (in canals or rivers) at a specific rate for irrigation inside large closed areas. Small sluices are usually at the head of secondary or tertiary canals to control water flow inside the high-dike compartments. Because of the area's flat topography, these sluice gates are designed to distribute floodwater to the fields during the flood season (Chapman *et al*., 2016). According to the province's regulation, each high-dike compartment should have two small sluice gates for flooding rice fields during the third season of the third year, following the 3–3–2 cycle. Large sluices are managed by the Irrigation Management Company of An Giang Province (Kingdom of the Netherlands, 2011), while small gates are operated by representative farmers.

Because of the location of An Giang in the flat delta floodplain, gravity irrigation is very limited. Therefore, pumps play an important role in irrigation and drainage systems in An Giang Province, especially at the farm scale. There are thousands of electric and petrol pumps in the province, including both collective and private pumping stations.

Existing irrigation and drainage strategy in An Giang Province

In low-dike compartments. In the dry season, water levels in the main rivers and canals outside of the low-dike compartments are usually lower than those in the tertiary canals inside the dikes, so farmers must pump water in to irrigate their fields. In the case that water levels inside the dike compartments are lower, water flows by gravity from the main canals into the fields through sluices, being distributed via tertiary canals. If excess rainwater remains in the rice fields, then pumps are used for drainage.

In the flood season, water levels in the main rivers and canals are higher than water levels inside the dikes, so water flows into tertiary canals through sluices by gravity. Floodwater may also flow over the dikes onto rice fields to create a wide flooded area. Usually, wealthy farmers do not work during the flood season whereas poor farmers catch wild fish and other common pool resources for daily consumption and to improve their incomes (Howie, 2011). Some farmers also grow floating rice or vegetables during the flood season. When the floods recede, floodwater is kept in the fields until the end of the flood season. At that time, farmers must pump water out of the fields to prepare the land for the next rice crop (winter–spring crop).

In high-dike compartments. The irrigation and drainage strategy inside high dikes is more or less similar to that in low dikes except that pumping costs for intensive rice systems and the capacity of pumps are usually higher. In the dry season, farmers pump water from the rivers via primary and secondary canals to tertiary canals, which are then used for irrigating the rice fields. Usually gravity flow is used if the water levels are higher outside the dikes than inside. To date, however, farmers in many high-dike compartments in An Giang completely close the intake sluice gates due to low gravity flow to fields via tertiary canals, preferring to use pumping stations for active operation of irrigation.

In the rainy season, water levels in the rivers and main canals are usually higher than those inside the high dikes. However, the water levels are lower than the top elevation of the dikes to ensure the safety of the third rice crop. Remarkably, farmers often have to pump excess rainwater from the fields to canals outside of the compartments to avoid waterlogging and damage to rice growth.

The provincial government of An Giang mandates adherence to a 3–3–2 cropping cycle inside the high dikes at the time that each high-dike compartment is constructed. Therefore, each dike compartment must be built with two high sluice gates of suitable width, one installed at the upstream end for water intake and one at the downstream end for water outtake. Following this strategy means that each high-dike compartment must have a final off-season during three continuous years of rice cultivation to allow floodwater to enter the fields and bring sediments and flush away toxins (SIWRR, 2012). This strategy, however, is applied only in very few compartments in An Phu, Cho Moi, Chau Thanh, and Phu Tan districts of the province. In reality, Phu Tan district is the only high-dike compartment area in An Giang Province in which the strategy has been maintained consistently (Figure 5). Explanations for why not all farmers apply the official strategy have been explored through interviews with farmers, and are presented in the results section.

The rule of the 3–3–2 cropping cycle has been successfully implemented in all compartments in Phu Tan district because it has a ‘closed’ dike system and a strict schedule of sluice gate operation managed by a water management board. This system is so-called ‘closed’ because it contains 28 high-dike compartments surrounded by closed main-road high dikes to protect these compartments. Water flow is managed by large sluice gates around the whole system. These large sluices regulate water flow in and out of the system following a strict operating schedule. Inside the system, each high-dike compartment has two smaller sluice gates that allow intake of water from the main canals to the rice fields. As Hung *et al*. (2012, 2014b) have shown, sediment input and distribution from floods in high-dike compartments are highly dependent on the position, capacity, and operation of the sluice gates.

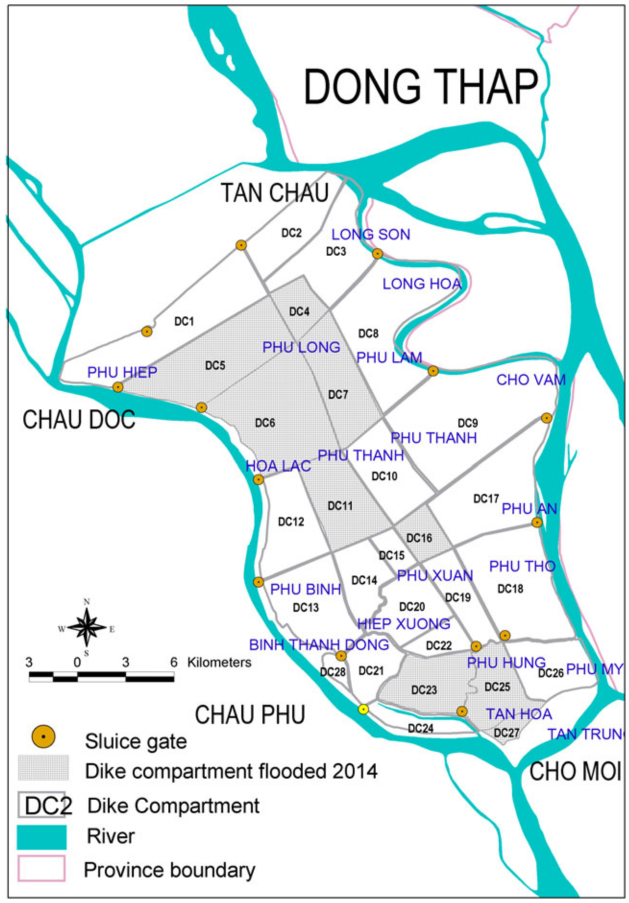

Figure 5. Model of the 3–3–2 cycle in Phu Tan district. Flooded compartments in Phu Tan in 2014 mean that 8 out of 28 high-dike compartments were flooded during the ninth rice crop in the third year. Each year, some compartments are flooded to ensure a rotation of flooding for all compartments. [Colour figure can be viewed at wileyonlinelibrary.com]

METHODOLOGY

Data collection and interviews

To understand local perspectives about water management, and specifically perceptions of challenges faced with existing farming systems and livelihood practices, we conducted 63 interviews. Sixty (60) semi-structured interviews with farmers were carried out in 6 communes in Chau Phu, Thoai Son, and Tri Ton districts of An Giang Province, and one commune in Thanh Binh district of Dong Thap Province (Figure 4). Of those, 45 interviews were carried out in either low- or high-dike areas of An Giang Province and 15 were conducted in a low-dike area of Dong Thap. Farmers in Dong Thap were surveyed to compare perspectives between areas with large-scale high-dike infrastructure

(An Giang) and one with very few high dikes (Dong Thap). Most interviews (37) were carried out in the Chau Phu district of An Giang Province because it has both low- and high-dike compartments protecting farms and because a diversity of farming systems are represented, including double rice, triple rice, and vegetable cultivation, as well as freshwater fish aquaculture. To reach farmers, we used a random sampling method which means each interviewee of the population has an equal chance of being chosen for the study. The number of interviews was not fixed in advance. Instead, farmers were interviewed until we reached saturation of information satisfying the research questions (Kumar, 2014). This means that if we had carried out additional interviews, we would not expect the information collected to be significantly different. In this way, the perspectives of farmers on differing farming systems could be collected to fully answer questions following the objective of the study. Eight (8) interviews were also conducted randomly in the high-dike areas of Thoai Son and Tri Ton districts to assess the consistency of farmers' responses across the research area. In addition, three (3) officials from the Department of Agriculture and Rural Development (DARD) of An Giang Province were interviewed in order to understand their perspectives on farmer livelihoods and difficulties faced in local water management.

Two sets of semi-structured questionnaires were created to interview farmers in either low- or high-dike areas. Each set of questionnaires had three sections: (i) farm characteristics; (ii) advantages and disadvantages of dike protection for farming systems; (iii) alternatives in farming systems for sustainable livelihoods in the future. The questionnaires used mostly open-ended questions to acquire more thought from farmers and to be open to unexpected answers (Kumar, 2014). To explore the perspectives of farmers related to the scope of this paper, questions about the 3–3–2 cropping system were included in the last section (iii). Once collected, all data were coded in Microsoft Excel following a method of thematic network analysis (Kumar, 2014).

To identify the perspectives of farmers about possible land-use transformation from double- and triple-rice crops to other cropping systems, we also analysed primary data from 998 farmer interviews provided by the Centre of Water Management and Climate Change (WACC) of Vietnam National University–Ho Chi Minh City. These interviews were carried out in 2015 throughout all districts of An Giang Province. WACC identified farm characteristics, farmer perceptions of climatic changes and socio-economic impacts on rice production, factors influencing crop transformation, potential livelihood solutions, and farmers' motivation and ability to transform their land use to potential alternatives.

Desktop analysis and literature review: Exogenous impacts of hydrological system. To understand the potential effects of climate change and hydropower development upstream along the Mekong River, we conducted a desktop analysis of the literature. Specifically, we reviewed journal articles and national reports addressing the impacts of these factors on hydrological regimes, agriculture, and livelihoods in the Mekong Delta. We also compared lessons from other regions of the world concerned with similar challenges, to explore and recommend potential measures to sustainably adapt to these changes.

RESULTS

Perspectives of farmers and local officials

All farmers interviewed clearly knew about the rule of the 3–3–2 cycle inside the high dikes. They responded that this rule was required by the provincial government. Farmers also understood that the rule was issued by the government in order to take advantage of floodwaters in bringing fertile sediments to the fields and flushing away toxic chemicals. The rule was designed to enhance soil quality inside the fields after an extended period of intensive rice cultivation. As reported by two farmers, local officials negotiated with all relevant farmers to reach agreement before construction of high dikes to replace low ones, and the rule of 3–3–2 was clearly explained. However, once the high dikes were completed and in operation, the rule of the 3–3–2 cycle was not applied in many compartments in the province. At the time of the interviews, farmers had been operating triple rice for an average of more than 10 years in the high-dike locations surveyed. Thus, water management following official policy remained ineffective, as a result of several factors as explored below.

Different reasons and constraints were given by farmers for why most of them avoided implementing the rule of the 3–3–2 cycle. First, several farmers supposed that the greater profit from growing an additional rice crop (compared to double crops inside low dikes before high-dike construction) made them not want to halt rice cultivation during any season. In addition, three farmers stated that they did not know what kind of work they would do during the flood season if their lands were flooded. Second, all farmers responded that local officials accepted their disregard of the rule. Since local officials are formally responsible for land and dike management, this encouraged the continued avoidance of the rule by farmers. Third, both local officials and farmers showed scepticism toward the supposed benefits of flooding the fields. Local officials expressed concern that the long-term inundation of floodwaters inside high-dike compartments would cause deterioration of the soil foundation of the dikes. Interestingly, 6 out of 12 farmers interviewed in high-dike areas of Chau Phu district claimed that the floodwater no longer brings fertile sediments and thus would not improve soil fertility. The floodwater in fact usually contains a large proportion of excess rainwater, which does not contribute to soil fertility, though it can still flush away leftover agrochemicals in the soil. It was further stated by three farmers that excess water stored for a period of 3–4 months during the flood season provides no benefits at all for the land and soil. Additionally, in some high-dike areas farmers cultivate fruit trees mixed with rice fields, which require many years to reach maturity, so farmers do not want to apply the rule for fear of destroying their trees. Finally, one farmer stated that the high-dike compartments were not in a closed large-scale protected area with operating sluice gates as in Phu Tan, so the rule of the 3–3–2 cycle would not be applied successfully.

Out of 45 farmers interviewed in An Giang, 40 (89%) responded that they prefer high dikes to low ones for their farming systems. Of those, farmers inside low-dike areas would like to upgrade their low dikes to high ones, while farmers inside high-dike areas appreciate the advantages the high dikes provide. First, high dikes improve residential safety and public welfare by protecting things such as transportation, schools, and hospitals from flood damage. Second, high dikes protect fields against flooding to enable triple-rice cultivation year-round, and, importantly, the rice market has been assured by the national government. Although all farmers were informed about the environmental degradation that the overuse of fertilizers and pesticides for triple-rice cultivation causes, they stated simply that rice is a traditional and easy-to-sell crop. Moreover, the additional rice crop offers a higher profit, especially for farmers who have large cultivated areas. It was also claimed that fertile sediments and wild fish are no longer being deposited in low-dike fields as before because of the hydropower development upstream along the Mekong River. Only five farmers disapproved of the high dikes, and these said it was because they found the additional profit from triple-rice cultivation to be low compared with the high production costs needed for labour, fertilizers, and pesticides. When asked about the possibility, most farmers inside the high-dike areas insisted they would not want to have floodwater enter their fields. Only three farmers in high-dike areas agreed they would halt a third rice crop to accept floodwaters into their fields for the purpose of improving soil quality.

In Dong Thap, 8 out of 15 farmers interviewed preferred high dikes to low ones. At just over 50%, this is much lower than in An Giang. This could be for the following reasons: (i) farmers are not willing to pay the 3-year investment costs required by the government as their financial contribution to high-dike construction; (ii) farmers have learned from their neighbours in An Giang about the high costs of triple-rice cultivation compared to double rice; (iii) Dong Thap has more double-rice cultivation in low dikes compared to the situation in An Giang, and farmers prefer not to change from their usual cropping system.

Local officials in An Giang also appreciate the advantages the high dikes provide. They stated that high dikes help farmers cultivate three rice crops per year to earn more money. Moreover, farmers can raise livestock such as poultry and cattle inside the high dikes. With high dikes, farmers do not have to worry that the overflow of floodwater into their fields will destroy the second rice crop in the harvesting phase as they do with low dikes. Residents have better welfare with safe transportation systems, schools, electricity, and public works thanks to high-dike protection. Regarding the 3–3–2 cycle, one official noted that the Department of Agriculture and Rural Development (DARD) of the province evaluates the implementation of the rule with high-dike compartments at the beginning of each year. However, there is no enforcement mechanism for the rule. Local and provincial authorities have no way of penalizing farmers for failure to implement the rule, so farmers have no disincentive for *not* following it. One official explained that if 85% of farmers inside a compartment disagree about the schedule of floodwater release as planned by DARD, officials have to follow and support the farmers. Notably, local officials also said that the rule is not good for farmers' fields because, in fact, there has not been a flood since 2011, and floodwater no longer carries with it fertile sediments due to changes in the water regimes they attributed to climate change and hydropower developments upstream.

With respect to the potential for a transformation of agricultural land use during the third cropping season, data from WACC were analysed. Out of a total of 998 farmers surveyed, the majority (685 or 68.6%) prefer to cultivate rice for a third crop each year (Figure 6). Of those, farmers inside low dikes want to upgrade their dikes to high dikes for triple-rice cultivation, and farmers already under high-dike protection want to continue their triple-rice cropping pattern. Vegetables are the second-most popular option for cultivation during the third cropping season (196 farmers, or 19.6%), which also require protection from floods during

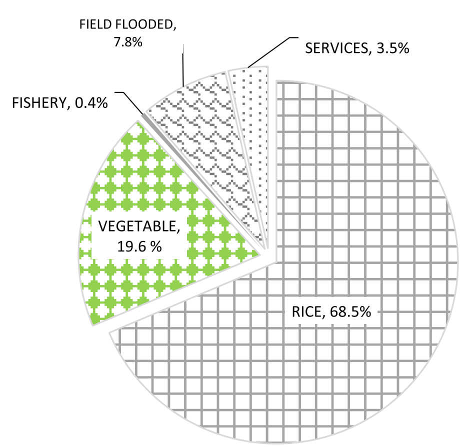

Figure 6. Preference of farmers for agricultural land-use transformation for the third cropping season (number of respondents). [Colour figure can be viewed at wileyonlinelibrary.com]

the flood season. Only 78 farmers (7.8%) would choose to have their fields flooded in the third season, while 35 farmers (3.5%) responded that they would change to non-farm goods and services during that season. Figure 7 shows the acceptability of, or interest in, land-use transformation (i.e. cropping system) for farmers with different cropping systems, divided into five levels: 'no', 'low', 'average', 'above average', and 'high'. Each farmer surveyed was asked to select one of the five levels to reflect their interest in transforming their cropping system for that season. Generally, the farmers only cultivating rice ('RICE') have the lowest willingness to change their cropping system, whereas those cultivating a combination of rice and other crops ('MIX') present the highest motivation to change. Farmers who do not grow rice at all ('#RICE') are situated between the two. These findings suggest that rice is still the most popular option for cultivation in the study area.

Effects of climate change and upstream developments along the Mekong River on water regimes downstream

Many studies have been done to model hydraulic and climate scenarios of potential impacts of climate change on water regimes in the Mekong Delta (Västilä *et al*., 2010; Konishi, 2011; Thompson *et al*., 2013; Richard and Tran, 2014; Santini and Paola, 2015; Hoang *et al*., 2016). Most of them have explored how different climate change scenarios would increase flood magnitudes during the flood season. By using the Mike SHE model, Thompson *et al*. (2013) conclude that the change in potential evapotranspiration due to climate change will strongly increase the flood discharge downstream of the Mekong River. By using a three-dimensional hydraulic model, Västilä *et al*. (2010) determine that average and maximum water levels and flood

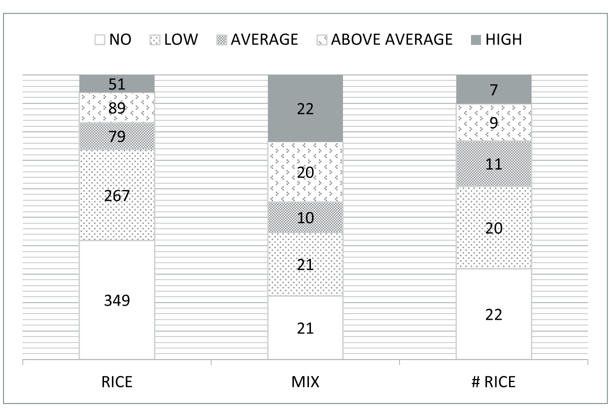

Figure 7. Acceptability of land-use transformation by farmers under different cropping patterns (number of persons) (Rice: mono-rice of double- and triple-cropping pattern inside low and high dikes, Mix: rice cropping pattern in combination with cultivating other crops such as vegetables or freshwater fish in the same or different fields; #Rice: no rice cultivation in the cropping system).

duration in the floodplain of the lower Mekong River Basin (the upper Mekong Delta) will increase in 2010–2049. This study also states that, 'Higher and longer flooding could cause damage to crops, infrastructure and floodplain vegetation, and decrease the fertile land area.' A study by Hoang *et al*. (2016) finds that seasonal and annual river discharges at different locations along the Mekong River will increase by 5–16% for future scenarios (2036–2065) due to the impacts of climate change. These projections contrast strongly with the observed changes in floodwater regimes in recent years at Chau Doc in An Giang Province as well as in the VMD as a whole. This may be attributed to uncertainties in the climate and hydraulic models used for simulations of the Mekong Basin. On the other hand, hydropower developments upstream were not included in the above-mentioned research, and could be a leading factor in the decrease seen in the delta's water regimes in recent years.

Indeed, several studies have been carried out on the hydropower developments upstream on the Mekong River in recent decades to identify their influence on water regimes and sedimentation downstream (Fredrik, 2011; Hung, 2012; Pearse-Smith, 2012; Hung *et al*., 2014a; Kuenzer *et al*., 2013; Manh *et al*., 2014; Scherer and Pfister, 2016). Most of these studies conclude that hydropower developments upstream have negatively impacted the water regimes and sediment loads on the main river branches and floodplains downstream. Specifically, water levels in the river are expected to fluctuate and decrease during the flood season due to floodwater storage in reservoirs for hydropower operations upstream. Consequently, negative impacts on ecosystems, agriculture, and floodplains downstream will be exacerbated in the future. Remarkably, Lauri *et al*. (2012) conclude, 'the operation of planned hydropower reservoirs is likely to have a larger impact on the Mekong hydrograph than the impacts of climate change'. However, climate change will amplify uncertainty in the estimated reservoir effects. Kuenzer *et al*. (2013) assess many studies of the problem and determine that dam operations upstream will likely increase average discharges during the dry season (potentially buffering the dry season impacts of climate change), yet decrease average discharge during the flood season. In terms of sediment dynamics, Manh *et al*. (2014) use a quasi-2D model and conclude that the high spatial variability of sediment transport inside the VMD's floodplains is a result of the combined impacts of ring dikes, the operation of sluice gates, the magnitude of floods, and tides. Findings such as these demonstrate that hydropower development dominates the changes in flood regimes and sediment dynamics seen in the VMD (contributing nearly 90% reduction of delta sedimentation), while climate change acts as a second-order effect (Manh *et al*., 2014, 2015). Thus, while climate change may exert a powerful influence on the river basin's hydrology, hydropower developments upstream will likely have a greater effect, reducing the magnitude of both flood regimes and sediment transport.

DISCUSSION

The findings of this research reflect farmers' weak motivation to implement the rule of the 3–3–2 cycle inside high dikes. Farmers do not perceive adequate direct benefits from allowing floodwaters to enter their fields for the final crop in a 3-year cycle either in terms of profit, overall cropping strategy, or soil quality enhancements, so many prefer to ignore the rule altogether. Farmers are, however, aware of the environmental consequences of continuous intensive rice cultivation, though they are not concerned enough to pursue a different, potentially less profitable, strategy. Although the 3–3–2 cycle appears not to be adequate at present for replenishment of fertile sediments in fields inside the high dikes (Chapman and Darby, 2016; Chapman *et al*., 2016), it does have the potential to flush away toxic agrochemicals and help avoid exhaustion of the soil. This rule has been until now the only available alternative option for rice cultivation inside high-dike compartments given the physical and structural conditions of the VMD. However, farmers have no incentive to follow the rule and no disincentive not to. As practised, this is an example of an ineffective irrigation and drainage strategy, where local officials cannot or do not manage farmers to ensure effective implementation. Therefore, we ought to consider how implementation of an irrigation and drainage policy might be more successful. One solution, as suggested in much of the literature, is that knowledge and awareness of farmers and local officials about a given policy proposal be further developed before attempting policy implementation (Franks *et al*., 2008; Li *et al*., 2005; Lukianas *et al*., 2006; van Alphen and Lodder, 2006; Ritzema *et al*., 2008; Ritzema, 2013; Wang *et al*., 2013).

However, the present research illustrates another lesson that should be considered. That is, the suitability for local conditions of a new rule or regulation issued by the government. In this study, farmers were not able to follow the rule because it was not suitable for all cases in an area where various physical conditions are present. However, the rule of the 3–3–2 cycle is still applied in some high-dike areas, such as in Phu Tan district, where the infrastructure system —consisting of dikes, canals, and sluice gates—is complete and maintained at a reasonably high level, enabling successful coordination to exploit the benefits of floods. Thus, the suitability of such a rule must be carefully evaluated. To do this, there should first be more thorough consultation with farmers and local officials about local conditions, needs, and preferences. Second, the government should apply the rule to a pilot area to test its effectiveness before deploying it on a large scale, to identify, for example, governance mechanisms or infrastructure characteristics needed to facilitate successful implementation.

To sustainably improve soil quality in the floodplains of the Mekong Delta, floodwaters must be allowed to enter the fields, following the natural hydrological dynamics of the delta. However, the situation currently faces several barriers to implementing such a change. Most important is the high demand from most farmers for high dikes for triple-rice cultivation. Our findings show that farmers most often oppose having their fields flooded because they prefer to earn additional income from a third rice crop. To persuade farmers to abandon the third crop under high-dike protection, better alternatives must be provided, such as crops other than rice that can be farmed in low-dike areas and which can help farmers increase their incomes more sustainably. Nonetheless, the advantages of high dikes should be taken into account, including flood protection for public infrastructure and homes. Instead, separate residential areas for farmers in low-dike areas could be developed that also protect against flooding (Roth and Winnubst, 2014). Another point to consider is that a high percentage of farmers prefer to cultivate rice in the VMD because of its market stability. Although profit from rice is low, farmers do not want to transfer to other crops because rice still brings a guaranteed income, especially to farmers with large landholdings. Rice is an product to sell on the market, as it has been assured for purchase by the Vietnamese government. This helps explain why many farmers want to cultivate a third rice crop under protection of high dikes. Other suitable measures that can improve soil and water quality for farming systems inside high-dike areas while also bringing advantages to farmers need to be further explored.

The literature suggests greater impacts on water discharges and sediment dynamics downstream from hydropower developments along the Mekong River than from climate change. This will likely be exacerbated in the future and is easily underestimated, considering the full construction of planned dams upstream. Usually, the impact of human interventions can be prevented more easily than that of 'natural' phenomena such as climate change. However, the case of hydropower development on the Mekong River is a complex transboundary political issue that faces significant challenges. For one, China and Myanmar have not been involved in the Mekong River Commission. The river flows through six countries but only four of them (Vietnam, Thailand, Laos, and Cambodia) follow the commission's 1995 agreement on regional cooperation for sustainable development (MRC, 1995). A transboundary agreement regarding hydropower operations has not been established and the problem may not be solved any time in the near future (Kuenzer *et al*., 2013). In general, underestimation of the effects of hydropower operations and water use for irrigation, etc., on downstream water regimes is a problem that must be taken into account for the VMD. Many negative effects on the delta, including freshwater shortage and saltwater intrusion, result from less floodwater retention capacity in the floodplain (Hoang *et al*., 2016). It is time for agriculture in the delta floodplain to adapt to these changes by using a more effective water management strategy with suitable irrigation and drainage systems.

Based on the findings of this research, the following measures at both local (farmers and local officials) and delta-wide (central government) scale are recommended to address the problem.

Recommended measures for irrigation and drainage systems at local scale

Some general 'hard' and 'soft' measures are recommended below for more effective and sustainable management of irrigation and drainage in the delta floodplain. However, in practice it is important that such measures be implemented following the SMART paradigm: with targets and actions that are *S*pecific, *M*easurable, *A*chievable, *R*ealistic, and *T*ime-bound (Mugabi *et al*., 2007).

'Hard' measures. Firstly, there should be regularly scheduled maintenance and upgrades for the water-related infrastructure. Both local authorities and farmers have to be responsible for this activity with financial support from the government. This will help prevent degradation of these structures and counter the claim that flood retention will destabilize the dikes, so they can continue to be used effectively for water management. Moreover, additional sluice gates and pumps must be built at suitable locations in both low- and high-dike compartments to increase water connection outside and inside dike compartments. In the future, more closed systems with sufficient sluice gates and canals such as the one in Phu Tan should be constructed for the high-dike systems. However, the operation schedule of sluice gates must be considered with respect to how best to take advantage of sediments in the floodwaters (Hung, 2012).

Construction of new high dikes should be halted to conserve space for maximizing flood retention capacity, based on low-dike and without dike for farming systems (Kingdom of the Netherlands and the Socialist Republic of Vietnam, 2013). Instead of building additional high dikes, investment should be put into improving low dikes by concreting them to avoid erosion risks from overflow to fields during the flood season and increasing the potential for gravity flow in these systems. Moreover, irrigation and drainage systems in dike-protected areas should have comprehensive water-related structures connecting them with the main canals in order to move water effectively in and out of the fields.

'Soft' measures. A framework for developing the knowledge and capacity of farmers and local officials should be built into irrigation and drainage system planning for effective water management. Ritzema *et al*. (2008; Ritzema, 2013) and Franks *et al*. (2008) conclude that capacity development activities are highly important for increasing farmer participation. This can occur via seminars or training workshops, where there is also a chance for increasing interaction, and thereby likely facilitating cooperation, between farmers and local officials. Water management will also be improved by linking tacit (local stakeholders') knowledge and explicit or scientific knowledge (Ritzema *et al*., 2008). According to research in this field, such knowledge integration can improve understanding of cause–effect relationships and thus proposals for water management strategies. Investigating and developing strategies for an effective water management policy under low- and high-dike protection would also be improved by the use of a decision support system and the participation of many different stakeholders and decision makers (Wang *et al*., 2013).

Early flood warning and flow-monitoring systems should be developed to forecast weather and flood magnitudes in the short and long term to help farmers prepare for and cope with small, average, and large floods. Moreover, quantitative analyses of suspended sediment should be carried out at monitoring stations in the floodplains of the VMD to better understand local dynamics and counter the present situation of data scarcity (Hung, 2012; Hung *et al*., 2014a, b). As noted by Chapman and Darby (2016), with such systems in place, local officials can more effectively establish and manage the schedules for flood release to the fields during average and large flood years to bring fertile sediments to the fields during the flood season. Even in large flood years, farmers need to open the sluice gates for a specific capacity and duration to allow floodwaters to enter fields protected by high dikes and trap sediment depositions (Hung *et al*., 2014b).

Water management strategy in the floodplain at delta scale

At the delta scale, there need to be government regulations in place aimed at reducing rice cultivation across the delta, which currently uses large quantities of water but brings low profits for the poor (those with small landholdings) or landless farmers (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2014). As many experts have argued, Vietnamese rice producers should focus on rice quality rather than just quantity as has been dominant, as current rice-cropping patterns typically just follow high production targets (Gibson and Kim, 2013). Triple rice is a result of the country's food security policy, instigated some 30 years ago to help the nation escape from a food shortage crisis following decades of war and political tumult (Käkönen, 2008; Kingdom of the Netherlands, 2011; Kingdom of the Netherlands and the Socialist Republic of

Vietnam, 2013). However, farmers' livelihoods are not sustainable under the current situation. When the government gives incentives in the form of a guaranteed rice purchase, thereby ensuring the market for rice consumption, farmers are not motivated to change to other cropping systems. Flood- or water-based crops should be encouraged and developed for use in the flood season to help farmers increase their incomes in line with creating a stable market for this type of product. In general, other cash crops or vegetables have the potential to bring higher profits for farmers, while lowering environmental stress and increasing resilience in the face of changing environmental conditions (Pretty and Bharucha, 2014; Tran Ba *et al*., 2016).

Additionally, exogenous factors such as reduction in sediment loads and changes in water flow along the main branches of the Mekong River must be taken into account. The effects of upstream developments cannot be managed by one nation alone. If these issues are not addressed, water management strategy will not be effective even if great efforts are made to improve sediment deposition and flood retention capacity in the floodplain. As Manh *et al*. (2014, 2015) and others have shown, the effects of upstream development are likely to be greater even than those of climate change for stressing the agro-ecology of the VMD and the livelihoods that depend on it. Therefore, the Vietnamese government should use diplomatic means, and call on international law, to increase the strength of rule of the Mekong River Commission (MRC) (2011), with the aim of reaching an agreement with all six Mekong River Basin countries to reduce the development of upstream dams and irrigation works and ensure the resilience of the VMD.

CONCLUSIONS

Farmers seem to be aware of the reasons for flood retention, but they do not share the same motivation as the government. They are interested in increasing their profits, many to escape from poverty. They do not gain direct benefit by worrying about future sustainability or wider system resilience, but not because of a total lack of knowledge or awareness of these issues. It does seem, however, that improved infrastructure and more effective cooperation between farmers and local officials will help. Yet, more important may be adjustments in government policy that take into better account farmers' needs and preferences in order to motivate change and enable a coordinated approach to water management. Big issues, big questions, of course, and there is not enough room to explore all of them in this paper.

The findings from this research are also relevant to other deltas around the world, especially those in developing countries where the perspectives of farmers trying to escape from poverty may be quite disconnected from scientific or governmental recommendations. In particular, we found that the success of a government-mandated irrigation and drainage strategy largely depends on its suitability for local conditions and preferences. This may require a more thorough process of government consultation with farmers and other local stakeholders before rule deployment, and the rule's feasibility should be pilot-tested before implementing it at a large scale. Farmers in the floodplain of the VMD are motivated to increase their incomes by intensifying rice cultivation without major concern for negative effects on the environment, but they are also the stakeholders with the best understanding of their farming systems and current local conditions. Although farmers have weak motivation for thinking about long-term sustainability, they are willing to follow a rule if they find it brings them direct benefits. To reduce this gap, awareness of the short-term benefits of sustainable livelihood strategies should be promoted, thereby strengthening the capacity of water management efforts. This study will help farmers and decision makers design and implement more effective irrigation and drainage strategies in line with local needs and preferences and responsive to flood regime changes, in order to adapt sustainably to both climate change and upstream hydropower developments in the Mekong Delta.

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