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# Recognizing ecosystem services for sustainable food production in The Mekong Delta, Vietnam

## Abstract

Increased agriculture and aquaculture production in the Mekong Delta during the last two decades has improved farmers' income, national export earnings and reduced poverty, but has also had negative impacts on the environment and ecosystem services (ESS) of importance to local peoples' livelihoods and well-being. This study identifies stakeholders' perceptions of ESS status and trends in the Mekong Delta and how these have been influenced by agriculture and aquaculture development. It evaluates trade-offs made between ESS under different development scenarios and stakeholders' preferences to these scenarios. The study was conducted through interviews, focus group discussions and questionnaire surveys with 375 stakeholders involved in fish (*Pangasius catfish*) farming in the An Giang province, shrimp (whiteleg shrimp) farming in the Can Gio district in Ho Chi Minh city and rice farming in the Tien Giang province, which represent major agriculture and aquaculture activities in the Mekong Delta. Most farmers were aware of provisioning ESS, which also was scored as the most important ESS, followed by supporting, regulating and cultural services. Almost all stakeholders perceived that the intensification of rice, fish and shrimp farming had had a negative impact

on the majority of the other ESS, which were identified as important for their livelihood and wellbeing. The majority (60–90%) of the stakeholders would prefer diversified and less intensive farming methods, even if this would lead to a slightly decreased production, mainly because less intensive systems was perceived to enhance several ESS and provide benefits to local communities. Such systems would probably help to increase the resilience of interlinked social-ecological systems in the Mekong Delta to future changes caused by upstream hydropower dams and climate change, while still protecting the environment and contributing to long term and healthy production of food.

## Introduction

The Mekong Delta is one of the largest and most densely populated wetland areas in the world and it plays a vital role in the lives of local people and the socio-economic development of the region (Berg, 2012, Smajgl *et al.* 2015). The Mekong Delta covers only 12% of Vietnam's area but supplies more than 50% of the country's rice production and is the most important region for rice production in Vietnam, with a total production of 23.6 million tons of rice in 2017 (Sebesvari *et al.* 2012, General

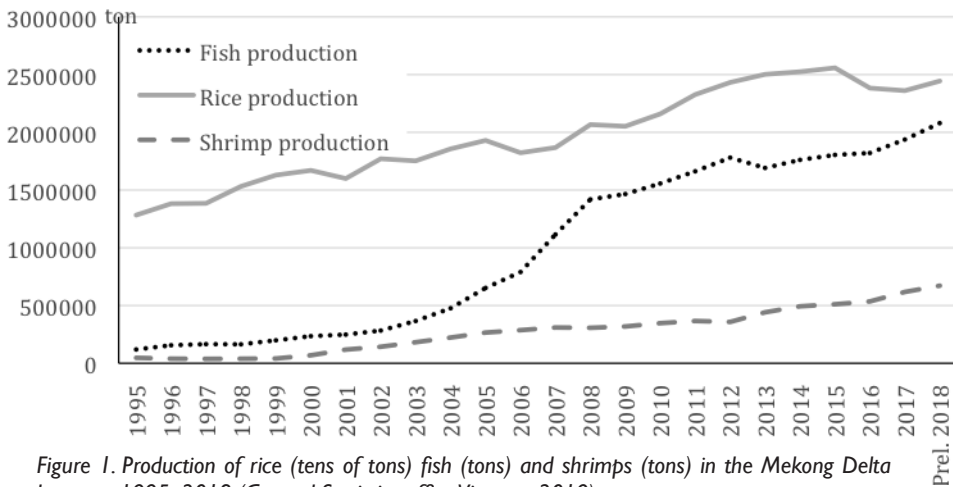


Figure 1. Production of rice (tens of tons) fish (tons) and shrimps (tons) in the Mekong Delta between 1995–2018 (General Statistics office Vietnam 2019).

Statistics office Vietnam 2019). Increased rice yields over the years have been achieved through more intensive farming methods, with two or three crops per year, and increased use of pesticides and fertilizers (Berg *et al.* 2012; Sebesvari *et al.* 2012).

This has contributed to increased agricultural income and reduced poverty, but it has also been followed by negative impacts on the environment and people's health (Dasgupta *et al.* 2007; Tam *et al.* 2015), which in the long run could impact on the overall production and quality of agriculture and aquaculture products from the Mekong Delta (cf. Luo *et al.* 2014). Tam *et al.* (2015) reported that farmers spraying organophosphates on rice fields resulted in both reduced growth and survival rates of fish, and Dasgupta *et al.* (2007) found that over 35% of 190 rice farmers in the Mekong Delta, experienced acute pesticide poisoning, and that 21% were chronically poisoned.

Intensified agriculture method could thus potentially impact negatively on the

yield of wild aquatic organism and on the ongoing expansion of aquaculture activities in the Mekong Delta, such as pangasius and shrimp farming and integrated rice fish-farming. Aquaculture production in the Mekong Delta provided in 2017 about 1.9 million tons of fish and 0.6 million tons of shrimps, representing 71% and 82% respectively, of Vietnams total production of fish and shrimp (General Statistics office Vietnam 2019) (Fig. 1). Between 1995 and 2017 the total production of fish and shrimps from aquaculture in the Mekong Delta increased 16 times (General Statistics office Vietnam 2019). The largest increase was in *Pangasius* catfish-farming, with an estimated production of 1.4 million tons in 2018, corresponding to almost 70% of the total fish-yield from aquaculture in the Mekong Delta (General Statistics office Vietnam 2019).

This quick expansion is generally regarded as an efficient mean for increased income and food security but it also generates risks for negative environmental im-

pacts, such as pollution and biodiversity change. In some cases it has even led to environmental disasters (Pullin, 1993; Folke *et al.*, 1998). Intensified fish production is often associated with increased fish stocking densities, high inputs of feed and antibiotics, followed by releases of uneaten feed, untreated wastewater, chemicals and disease outbreaks (Pullin, 1993; Da *et al.* 2011). This increases the pressure on ecosystem functions and impacts on ecosystem services (ESS), which in turn affects people's livelihood and the development of the aquaculture industry itself. This has happened many times before and is often due to a general lack of ecological understanding about the strong complementarity between the supporting environment and the cultivation.

Fish and shrimp farming as well as rice farming relies on many resources and must be viewed in the broad context and not as an isolated sector. It is embedded in the economy and heavily dependent on ecosystem services for a sustained production (Folke *et al.*, 1998).

In this paper we argue that if agriculture and aquaculture development is to be ecologically sustainable, efforts must be directed towards methods that make use of the natural environment without severely or irreversibly degrading it. There is a need for a holistic ecosystem view where the benefits derived from ecosystem services must be recognized and play an important part in agriculture and aquaculture development (Folke *et al.* 1998). A focus on ecosystem services also emphasizes that these systems are integrated parts of social-ecological systems in which they are embedded, and therefore need to be adjusted to

the context and carrying capacity of those systems.

The Vietnamese Mekong Delta has one of the largest and lowest elevated delta plains in the world, which is under heavy pressure from climate change (Minderhoud *et al.* 2019). At the same time upstream dam constructions change the flow of water and sediments with dwindling sediment loads that can counterbalance ongoing sea-level rise and river water that can flush salt water during the wet season (Smajgl *et al.* 2015; Minderhoud *et al.* 2019). Increasing salinity levels in the Mekong Delta have substantially reduced agricultural productivity, in particular for crops and varieties with a low tolerance to salt (Smajgl *et al.* 2015). Substantial economic losses are estimated to occur for farmers because of 20–65% reduced inputs of nutrient rich sediment, which must be balanced with substantial investments in fertilizer inputs to maintain present production levels (Smajgl *et al.* 2015). To adapt to these increasingly unpredictable conditions, following from climate change and upstream dams, there is a need for altered cropping systems that are more resilient to future changes (Smajgl *et al.* 2019).

This paper builds on a number of studies, with the overall objective to provide guidance and technical support to local policy makers and managers in the Mekong Delta on how future agriculture and aquaculture systems could be designed to maximize both the net benefits that society receives from agriculture production and the services provided by ecosystems. Our results show that dominating agriculture and aquaculture systems in the Mekong Delta does not meet these goals and argues that

they should be re-engineered to deliver greater social and environmental benefits as well as be made more resilient to meet future demands for food security under increasingly unpredictable environmental conditions.

## Methods

### Research approach

This work was done in the wake of the forming of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (Diaz *et al.* 2015), which was established in 2012. It was made in response to a need to operational the concepts under the IPBES at local scales and the need for more assessments of ecosystem services especially in developing countries. It was also felt that the aim of IPBES to “strengthening the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development” was well aligned with research outlined below.

The studies were done in close collaboration with local stakeholders and the analysis builds on their perceptions of ESS and how these contribute to their livelihoods. These participatory processes were expected to capture, from the bottom-up, stakeholders’ perceptions of ESS and foster the incorporation of different types of knowledge in decision making processes (Lopez and Videira, 2016). As highlighted by several recent reports and global processes such as IPBES, IPCC and CBD, local participation and knowledge must play a critical role in identification of ESS and scenario development (Kok *et al.*, 2016;

Lopes and Videira, 2016). Local implementation of ESS assessments has been seen as a major challenge, especially in developing countries, and examples of participatory approaches for ESS identification, where stakeholder groups are jointly engaged in scoping tasks are still scarce (Lopes and Videira, 2016). However, with the aim to establish successful environmental strategies for sustainable development of agriculture and aquaculture, farmers must be involved, and their opinions and preferences, as well as their attitudes towards ESS must be understood (Quinn *et al.*, 2015; Berg *et al.*, 2016).

Our approach shows how place-based research on the conceptualization and articulation of ESS can help to identify the demand and prioritization of ESS among local stakeholders in the Mekong Delta of Vietnam. The concept of ESS is quite new in Vietnam but has recently been used to provide guidance for sustainable aquaculture/agriculture development in Southern Vietnam (Berg *et al.*, 2016; McDonough *et al.*, 2014), and gained increased interest by the Ministry of Natural Resources and the Environment (MONRE) through the ProEcoServ project. In this study the “Toolkit for Ecosystem Service Site-based Assessment (TESSA)” (Peh *et al.*, 2013) and “Integrating ESS in Strategic Environmental Assessment: A guide for practitioners” (UNEP 2014) were used to guide the work. The close consultation with local stakeholders provided opportunities for non-specialists to participate in the analysis, and provided capacity building through “learning by doing”, which is an important step for adaptive co-management of social-ecological linked systems.

## Research design and study area

The methods and results presented in this paper builds on a number of research projects related to three aquaculture systems conducted in three different types of wetlands in the Mekong Delta; *Pangasius* catfish farming along the Mekong River (Nguyen *et al.* 2017), rice-fish farming in floodplains (Berg *et al.* 2016) and shrimp farming in mangroves and estuaries (McDonough *et al.* 2014) (Fig. 2).

A number of complementary methods such as field observations, Key Informant Panel (KIP) interviews, group discussions (PRA) and questionnaires were used to

identified different stakeholders (including fish, shrimp, mollusc, rice and fruit farmers, fishermen and local officer) awareness and perception of how these systems depends on ecosystem services, and how the intensification of these agriculture/aquaculture systems have impacted on supporting, provisioning, regulating and cultural services both in the past and in the future. The perceived trends in especially provisioning, regulating and supporting ecosystem service were seen as an indication of systems environmental sustainability. As this was the view of local stakeholders depending the same ecosystem servi-



Figure 2. The Mekong Delta and the location of the My Hoa Hung commune in the An Giang province, Cai Be in the Tiền Giang province, the Lang Sen Wetland Reserve (LSWR) in the Long An province, and Can Gio close to the Ho Chi Minh City, where the research was conducted.

ces for their livelihoods and wellbeing the trend also indicated the systems social sustainability.

Stakeholders were also asked to state their preferences to different future scenarios of agriculture/aquaculture development, including a continuation of the current system, a more intensive systems or a less intensive systems. As the stakeholders' choice indicated their perception of how the chosen system would affect a combination of environmental, financial and social factors and in turn their livelihoods and wellbeing, this was seen as an indicator of the systems overall sustainability.

The field work on *Pangasius* farming was conducted in the My Hoa Hung commune in the An Giang province in 2014. The commune is surrounded by the Mekong River, and has a large number of *Pangasius* catfish households. In 2015 *Pangasius* aquaculture activities covered 5370 ha and are expected to reach 7720 ha in 2020 in An Giang. *Pangasius* catfish constituted more than 90% of the annual production of 260,000 tons of farmed fish (Nguyen *et al.* 2017). The close by city Long Xuyen is considered the center of aquaculture, with *Pangasius* catfish being the dominant species (Fig. 2). A total of 155 stakeholders participated in the study and included *Pangasius* catfish farmers (35), other aquaculture farmers (35), rice/vegetable farmers (50), artisanal fishermen (20) and ecotourism operators (10), which all were identified to depend on the Mekong river and associated ESS.

The field survey on rice and rice-fish farming were carried out in the Cai Be district in the Tien Giang province and the

Lang Sen Wetland Reserve (LSWR) in the Long An province (Fig. 2). The study was conducted in 2014 and included a total of 60 rice farmers. The farmers were chosen according to the type of rice production system they had, and focused on monoculture rice farming and integrated rice-fish farming with and without integrated pest management strategies (IPM).

The Cai Be district is a representative rice-producing area in the Mekong Delta with both intensive rice farming and integrated rice-fish farming (Berg and Tam 2012). The area around Cai Be district has a very good irrigation system consisting of a network of many canals and natural rivers. The Lang Sen Wetland Reserve (LSWR) covers 3280 ha and is one of the few remaining natural wetlands in the area. Most rice production is located in the northeast part of the area. The relatively high biodiversity found in LSWR is important for local people's livelihoods, and fish are the most significant protein source for the people in LSWR. The LSWR represents an area with a relatively short history of agricultural practices and resembles a natural wetland, and provided an opportunity to compare these farmers' agriculture strategies and perceptions of ecosystem services with the farmers from the more intensified agricultural area of Cai Be district.

The study on shrimp farming was conducted in the Can Gio Biosphere, Ho Chi Minh city in 2012 (Fig. 2). Can Gio's proximity to Ho Chi Minh City and shrimp farming activity around the buffer zones make it an ideal location to examine the anthropogenic values and its relationship to ecosystem services, shrimp aqua-

culture development, and wetland conservation. In 2012 Can Gio encompassed around 1514 officially recorded operational shrimp farms.

157 individuals participated in the study, consisting of 42 participants from the core area (16 fisher folk, 8 mollusk farmers and 16 park rangers) and 118 participants (mostly shrimp farmers) in the buffer zones.

## Results

### **Stakeholders awareness and dependence on ecosystem services**

All stakeholders could easily relate to provisioning services (100%) and overall these services were seen as the most important category of ESS among the majority of stakeholders interviewed. (Fig. 3 and 4). This was especially pronounced for fishermen, fish-farmers and rice-farmers, while ecotourism operators ranked cultural services higher (Table 1). This clearly exemplify that different stakeholders have different preferences depending on their dependence on ESS for their livelihoods. Fish farming and rice production are major economic activities in the Mekong Delta and provide the basis for peoples' livelihood and income and it is no surprise that provisioning ESS, such as cultivated goods, were ranked the highest (4.6 of 5) (Table 1). Both provide tangible benefits, which make these services explicitly valuable to the farmers.

Supporting and regulating services had lower scores than the provisioning services probably because of their more invisible benefits, and the fact that they have a slower and more indirect effect on the sta-

keholders' livelihoods and wellbeing (Oort *et al.*, 2015; Quinn *et al.*, 2015) (Fig. 3 and 4). In some cases, however, these services were seen as quite important, when they had a clear link to the stakeholder economic activities (eg. nutrient circulation for rice farmers, Table 1).

Regulating ESS was ranked as the second most important category of ESS, and especially water quality/clear water was ranked as very high among all stakeholders (Table 1). Fishermen, fish-farmers and shrimp-farmers had the highest ranking of these services among all stakeholders, indicating their dependence and awareness of the importance of a good water quality to support their activities. Both *Pangasius catfish* and shrimp farmers had experienced productions losses because of decreased water quality, often caused by their own activities, which obviously had made them more aware of this regulating ESS and how it benefited their activities (McDonough *et al.* 2014, Nguyen *et al.* 2017).

Rice farmers living in the less impacted LWSR area ranked water quality lower, despite they still used river water for cooking and washing, and it seemed as the past history of a fairly good water quality in this area made them less concerned about water quality problems and less aware of the importance of this ESS for their wellbeing (Berg *et al.* 2016).

Similar these stakeholders ranked natural enemies/disease control lower than the others, whereas *Pangasius catfish* farmers who suffered heavily before from diseases ranked this quite high (Table 1).

Supporting service, such as nutrient cycling and habitats for wildlife were seen



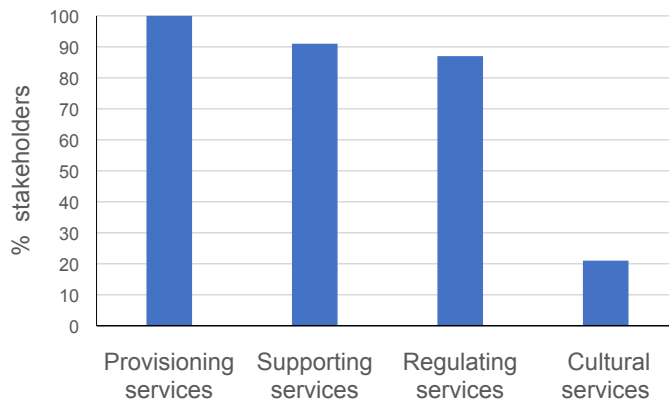


Figure 3. Awareness of ecosystem services among 150 stakeholders in the My Hoa Hung commune along the Mekong River in the An Giang province in 2014.

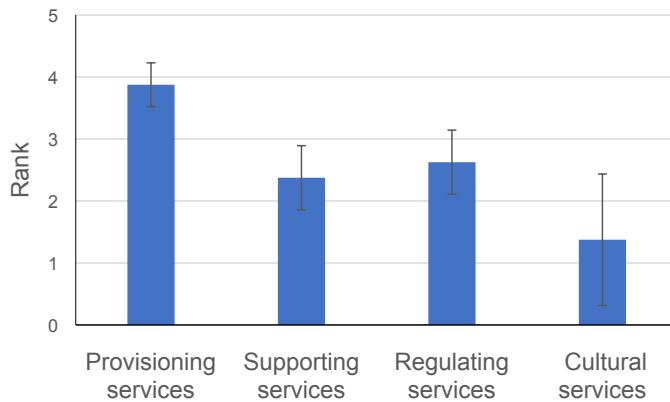


Figure 4. Ranking (1–4, where 4 most important) of the importance of ecosystem services among 210 stakeholders representing 8 different stakeholders group in the My Hoa Hung commune along the Mekong River in the An Giang province and in the Cai Be district in the Tien Giang province and the Lang Sen Wetland Reserve (LSWR) in the Long An province in 2014.

as less important and also somewhat difficult for the stakeholders to relate to (Fig. 3 and 4). Still rice farmers seemed to be more aware of and ranked services like soil formation, nutrients cycling higher than the other stakeholders, again indicating the importance of having own experiences to acknowledge the value these services (Table 1).

Cultural services were the most difficult services for the stakeholders to related to and also those which were ranked the lowest (Fig. 3 and 4 and Table 1). Still most farmers could relate to aesthetic values and festivals after some discussions and explanations.

Table 1. Importance (Likert scale 1–5 where 5 most important) of identified river ecosystem services to different stakeholder groups in the My Hoa Hung commune along the Mekong River in the An Giang province in 2014.

	<b>Pangasius catfish farmers</b>	<b>Rice/ vegetable farmers</b>	<b>Other aquaculture farmers</b>	<b>Ecotourism operators</b>	<b>Artisanal fishermen</b>	<b>All</b>
	(N = 35)	(N=55)	(N=35)	(N=10)	(N=20)	
	mean	mean	mean	mean	mean	mean
<b>1. Provisioning services</b>	<b>4</b>	<b>3,5</b>	<b>3,8</b>	<b>3,3</b>	<b>4,2</b>	<b>3,8</b>
a. Clear water	4,1	3,5	3,9	3,2	4,3	3,8
b. Cultivated goods	4,5	4,5	4,7	4,4	4,6	4,6
c. Food supply	2,9	2,5	1,9	1,8	2,3	2,4
<b>2. Supporting services</b>	<b>3,1</b>	<b>3,4</b>	<b>3,3</b>	<b>3,3</b>	<b>2,8</b>	<b>3,2</b>
a. Soil formation	0,8	0,9	0,7	0,9	1,1	0,9
b. Nutrient cycling	3,2	3,6	3,2	3,0	2,8	3,3
c. Ecosystem maintenance	2,3	2,8	3,0	2,0	3,3	2,7
<b>3. Regulating services</b>	<b>3,3</b>	<b>3,2</b>	<b>3,1</b>	<b>3,2</b>	<b>3,0</b>	<b>3,2</b>
a. Flood regulation	2,8	3,1	2,9	2,8	3,1	3,0
b. Disease regulation	3,7	3,3	3,3	2,5	-	3,3
c. Climate regulation	2,8	3,4	1,0	1,0	2,0	2,0
d. Water quality maintenance	3,1	2,8	2,9	3,2	2,5	2,9
e. Landslide control	0,8	0,9	0,7	0,9	1,1	0,9
<b>4. Cultural services</b>	<b>2,4</b>	<b>1,8</b>	<b>1,3</b>	<b>3,5</b>	<b>1,9</b>	<b>2,2</b>
a. Recreational fishing	2,3	1,8	1,0	4,3	2,5	2,3
b. Ecotourism	2,8	2,0	-	3,6	-	2,8
c. Research	4,0	2,0	1,0	4,0	1,0	2,4
d. Cuisine	-	-	-	4,5	-	4,5
e. Kayak	2,3	1,8	1,3	2,0	2,0	1,8

### **Stakeholders perception of status and trends in ecosystem services**

The majority of the farmers felt that provisioning ESS, such as the production of rice and fish had increased and would continue to increase in the future (Fig. 5). However, most farmers also felt that this had been achieved through a decrease in other ESS (Fig. 5). Some rice farmers, applying

intensive rice monoculture felt that the rice yield had peaked and would not be possible to increase in the future (Berg *et al.* 2016).

Most stakeholders felt that the yield of wild organisms (animals and plants) had decreased and would continue to decrease in the future, mainly because of increased water pollution and intensified farming methods (Fig. 5). Many said that less in-

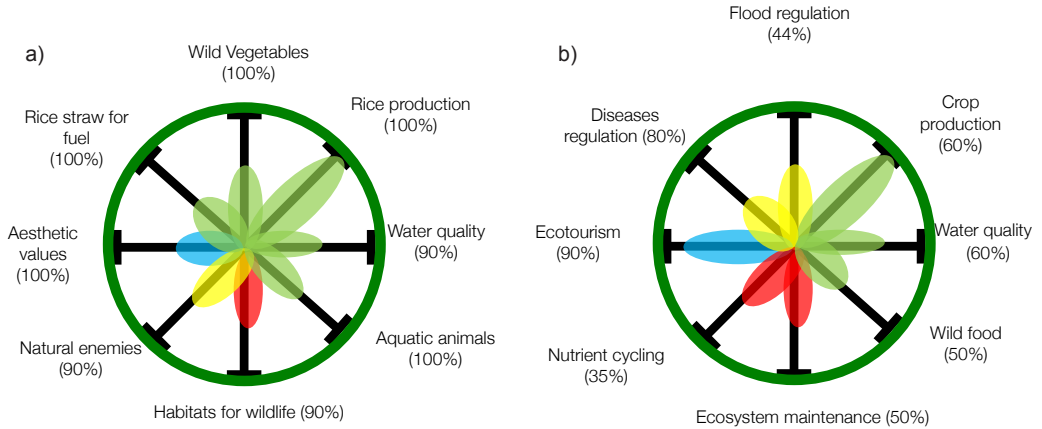


Figure 5. Perceived change (decrease=less than 50% of the radius of the circle; increase=more than 50% of the radius) of ecosystem services among: <sup>a)</sup> 60 rice farmers in the Cai Be and the Lang Sen Wetland Reserve during the last 15 years; <sup>b)</sup> 150 stakeholders in the the My Hoa Hung commune along the Mekong River during the last 5 years in 2014. Figures in the brackets shows the % stakeholders agreeing to the proposed change. Provisioning ESS are represented by green color, regulating ESS by yellow color, supporting ESS by red color and cultural ESS blue color.

tensive and more integrated farming methods could improve the situation (Berg *et al.* 2016).

The majority of farmers felt that the water quality had decreased and would get worse in the future (Fig. 5). The use of agrochemicals and the environmental pollution from farms, households and industries, were seen as the main reasons for the decreased water quality. A reduced use of chemicals and better wastewater treatment systems were suggested as possible solutions to improve the water quality, but this would require improved education and know how (Berg *et al.* 2016 Nguyen *et al.* 2017).

People were also concerned about a declining status of disease regulation, which was perceived to be in a bad condition with increased occurrence of pathogens and antibiotic contamination, mainly because of intensive agriculture and aquaculture practices (Fig. 5). The status of this service was expected to decrease even

further in the future because of a continued expansion and intensification of agriculture and aquaculture practices (Berg *et al.* 2016, Nguyen *et al.* 2017). Most farmers felt that there also had been a decline in natural enemies to pests, mainly because of a high use of agrochemicals and habitat destruction (Berg *et al.* 2016).

Overall the farmers felt that the habitat for wildlife had decreased (Fig. 5). Environmental water pollution, loss of connectivity between rice fields and surrounding habitats, intensive farming, high use of agrochemicals and illegal fishing gears were mentioned as the common reasons for the decline (Berg *et al.* 2016; Nguyen *et al.* 2017). Rice farmers in Cai Be district said that the low water levels kept for the rice created problems for aquatic organisms and that the use of machines, instead of harvest by hand, had limited the breeding time for many animals (Berg *et al.* 2016).

Stakeholders around the Mekong River

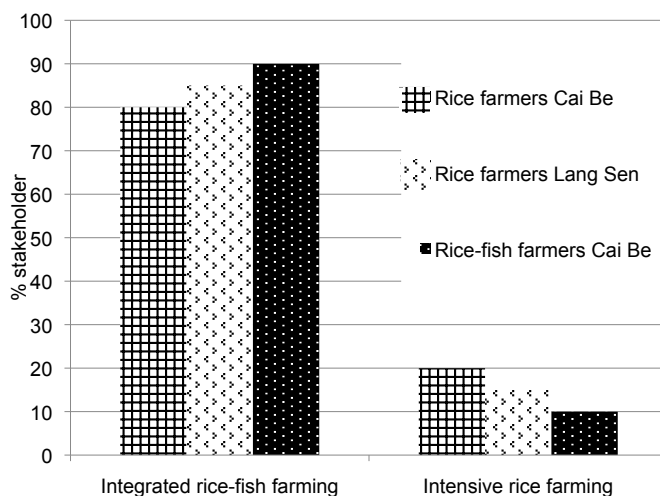


Figure 6. Percentage of rice farmers and rice–fish farmers in Cai Be and LSWR in 2014, who were in favour of intensive rice monocropping, with a high rice yield but lower quality of other ecosystem services, or more extensive integrated farming systems, with lower rice yield but higher quality of other ecosystem services.

felt that the river is an important habitat for many wild aquatic species, but that it was under increasing pressure because of increasing human activities such as agriculture and aquaculture and increased number of boats and industries (Nguyen *et al.* 2017).

Cultural services, were generally seen to be in a good status among stakeholder along the Mekong River, while the majority of the rice farmers in Cai Be experienced a decline in cultural services due to intensive farming systems, use of machines and urbanization (Fig. 5). Many rice farmers felt that younger people did not see the countryside in the same way as older people. They did not appreciate the aesthetic value and the life of being a rice farmer, but preferred to move to the cities to work. This was believed to be the future trend. However, some farmers believed that cultural ESS would increase in

the future, because of better income and more festivals. With more tourists visiting the Mekong Delta, there would be increasing opportunities for ecotourism, scenic landscapes, recreational fishing and festivals (Berg *et al.* 2016, Nguyen *et al.* 2017).

### Stakeholders preferences to future farming systems

The majority of all stakeholders preferred development scenarios where future agriculture and aquaculture systems would be less intensive compared to the current systems (Fig. 6–8).

In Cai Be and Lang Sen 83% of the farmers preferred rice farming systems that would enhance or preserve multiple ESS at the expense of somewhat decreased rice yields (Fig. 6). However, if the rice yield would become less than 6 tons/ha/

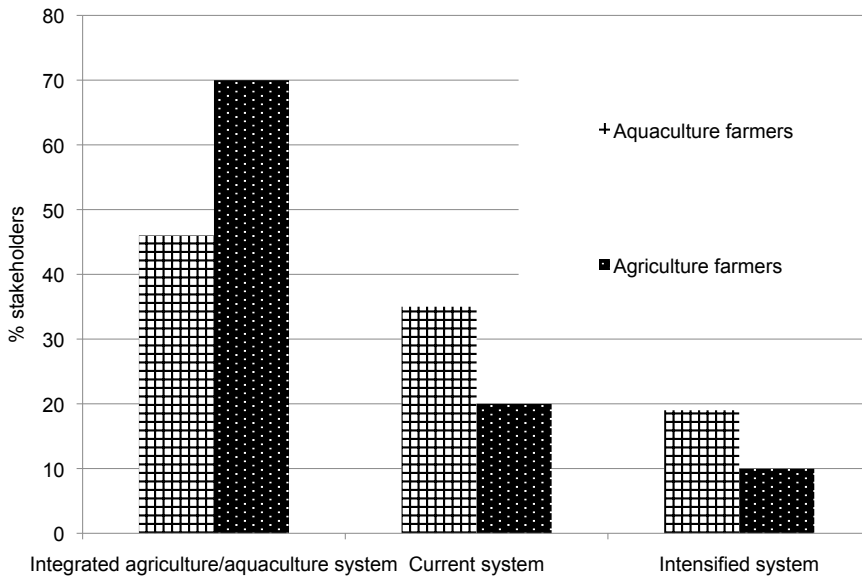


Figure 7. Preferred development scenarios of *Pangasius* farming by stakeholders in the My Hoa Hung commune along the Mekong River in the An Giang province in 2014, divided into aquaculture farmers ( $n = 90$ ) and agriculture farmers ( $n = 60$ ).

crop, they might re-consider their choice. The rice–fish farmers experience was that an integrated system could provide both many ESS and an acceptable rice yield, but that this was hard to establish since neighboring farmers used a lot of pesticides that influenced negatively on their rice–fish fields. Still, they were positive about the complementary income from fish, and wanted to continue with integrated rice–fish farming, because it diversified their income opportunities and provided benefits to the environment (Berg *et al.* 2016).

Along the Mekong River the majority of stakeholders (56%), dominated by agriculture farmers, preferred the development of a less intensive integrated production system of *Pangasius* catfish farming, and only 15% supported large-scale intensive

*Pangasius* catfish farming (Fig. 7). The remaining stakeholders (29%) preferred the current *Pangasius* catfish production system, mainly because they were unwilling to take the risk of changing into a new system. Less than 20% of the aquaculture farmers were in favor of large-scale intensive *Pangasius* catfish farming (Nguyen *et al.* 2017).

The most important advantage with a less intensive integrated system was that it would enhance ESS, that would benefit local stakeholders, especially in relation to crop cultivation such as rice, vegetables and fruits. It was also seen as an advantage that the integrated system could use wastewater from *Pangasius* catfish ponds for rice and vegetable irrigation, and thereby reducing water pollution and pathogens,

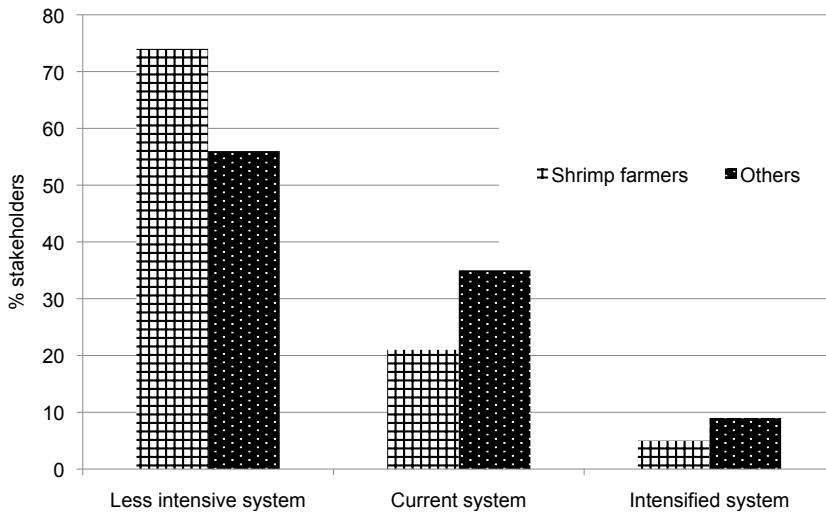


Figure 8. Preferred development scenarios of shrimp farming by stakeholders in the Can Gio Biosphere in 2012, divided into shrimp farmers ( $n = 118$ ) and others (fisher folk, mollusc farmers and park rangers) ( $n = 42$ ).

and at the same time reducing the input of commercial fertilizers. Overall it was seen as an appropriate and sustainable alternative to the other scenarios (Nguyen *et al.* 2017).

Similar, the majority of shrimp farmers in Can Gio district showed strong preference (74%) for a less intensive production of shrimps and only 5% supported a more intensive production system, while the remaining 21% preferred the current system (Fig. 8). Historical experiences with shrimp farming, in particular, negative experiences with shrimp disease outbreaks had influenced shrimp farmers to value ESS delivered at the natural state more. Significantly, most shrimp farmers highlighted that the value of living in Can Gio was characterized by the clean and natural area and that rapid and heavy urbanization was something the community wanted to avoid. Most shrimp farmers agreed on the

negative impacts of intensive shrimp aquaculture but also stressed how it had helped to improve the local economy. Farmer groups also declared that aquaculture is necessary for an area like Can Gio to develop and improve community livelihoods through access to modern day services and facilities (McDonough *et al.* 2014).

## Discussion

Our results indicated that stakeholders' preferences of ESS are context specific, but there are also some overall trends that are similar. All stakeholders were most aware of provisioning ESS, in the form of cultivated goods, and ranked these the highest. Thus, it is quite clear that in an area dominated by agriculture/aquaculture, such as the Mekong Delta, production of provisioning ESS, such as fish and rice, are of key importance for the liveli-

hoods of the majority of the stakeholders, and a sustainable development must assure a continued long term production of these provisioning ESS.

Increased yields of rice, fish and shrimps have provided export earnings, reduced poverty and helped the provinces of the Mekong Delta to develop financially. However even if the level of production and the financial gains are important criteria for measuring success also the impact on livelihoods and whether it delivers benefits to society with minimal impacts on the environment are critical factors to consider (FAO, 2010). From an economic point of view, an increased production of scale may be a rational way to increase the profit, as it decreases the marginal cost for each produced unit. However, with increased production of scale also the risk of crossing the carrying capacity of the supporting environment increases, with increased risks for negative environmental impacts.

Too often it has been forgotten that farming systems are integrated parts of the environment and highly dependent on well-functioning ESS provided by the life supporting ecosystem. If this is not recognized it is only a matter of time before the farming system will impact on its own activities.

Our studies showed that the majority of the stakeholders (dominated by farmers) felt that intensified production methods had led to a deterioration of most of the other ESS, that had been identified to be of key importance to their livelihoods and wellbeing. This is in accordance with the findings from the recently published first global IPBES report (Diaz *et al.* 2019), which highlights that the main driver of

biodiversity loss and degradation of ESS are land use changes often related to intensified farming methods.

Thus, there is a need to rethink strategies for food production in the Mekong Delta, to avoid unwanted trade-offs, where long-term benefits from multiple ESS are lost for short-term financial gains from single crops. Such losses of ESS, not only have direct impact on people's wellbeing, but also restrict future options for alternative and diversified livelihoods, which may be critical for local people's ability to adapt to changes following from upstream dams on the main stream of the Mekong River and climate change (Smajgl *et al.* 2015; Tessler *et al.* 2016).

The Mekong Delta is currently probably one of the most vulnerable deltas in the world, exposed to a multiple of different stressor including intensive land and water use changes, industrialization, urbanization, climate change and upstream dams and the task to prepare the Mekong Delta for an uncertain future is complex and challenging (Smajgl *et al.* 2015).

However, the social-ecological systems in the Mekong Delta have a long history of "living with change" and knowledge on how to take advantage of change to enhance diversity and livelihood opportunities. This ability should be carefully managed to design systems that are more resilient to an increasingly uncertain future. There are signs of a shifting attitude among authorities in the Mekong Delta and it is important to act on emerging and remaining opportunities, as studies indicate that the adaptive capacity of central provinces in the Mekong Delta has become very low (Smajgl *et al.* 2015 ).

Our studies show that the intensification of farming systems in the delta has degraded several ESS and build on monocultures which are vulnerable to increasing variable environmental conditions, pests and diseases. Future strategies for food production should instead build on a diversification of farming systems with a reduced use of chemicals and an increased recycling of nutrients. There is a need for a system view where farming systems are designed to enhance or at least not degrade ESS for a long term and healthy production of food. Currently the intensive use of chemical in agriculture and agriculture impact negatively on the production of wild organism and even on the farmed species. The farming system must be seen as part of a social-ecological system with an aim to safeguard the producers' livelihoods, particularly, the small-scale farmers, which constitute the backbone of the aquaculture and agriculture sector, while at the same time ensuring food quality and safety as well as environmental integrity.

Crop and land-use change could be important ways to adapt to future changes, and have the potential to substantially mitigate livelihood threats and could include changing from two or three crops of rice to a mixed regime of rice and aquaculture (Smajgl *et al.* 2015). As indicated by our results, this could build on existing knowledge and willingness to adopt less intensive integrated farming systems in the Mekong Delta, and would probably not only help local communities to adapt to future changes, but also provide options for diversified and sustainable food production systems, and improve farmer's income (Smajgl *et al.* 2015).

However, this would require coordinated agricultural extension efforts to address adaptation impediments among farmers such as lack of education, skills and knowhow, high economic vulnerability and a desire to continue with present livelihoods (Smajgl *et al.* 2015, Berg *et al.* 2016, Nguyen *et al.* 2017)

Adaptation in this complex context needs to be implemented as a multilevel strategy that considers the local requirements and constraints as well as re-evaluating central government plans for increased export oriented production of fish, shrimp and rice (Smajgl *et al.* 2015). Conservative governmental plans can easily create institutional impediments to change and creates path dependencies and lock-in effects for households (Smajgl *et al.* 2015).

An overall strategy for enhanced adaptability and resilience is also to safeguard the status and diversity of ecosystem services (Walker and Salt 2006). This requires an improved awareness of the multiple benefits delivered by ecosystem services among different stakeholders, including farmers and governmental officers.

A recent external evaluation of the IP-BES work highlights that there is still a gap in the implementation of ecosystem service assessments at local and national scales and it believed that the studies above have helped and inspired institutions in Vietnam to further apply these concepts to identify strategies for sustainable development of agriculture and aquaculture development. The studies referred to in this paper, were done in close collaboration with national universities and NGO's, like WWF and governmental organisations like the Ministry of Natural Resources and



the Environment (MONRE) in Vietnam. A mode of “learning by doing” approach, clearly strengthened the science-policy interface for assessing ecosystem services for sustainable development by both establishing closer contacts between participating institutions, but also a balanced production of peer reviewed academic publications (Nguyen *et al.* 2017; Berg *et al.* 2016; McDonough *et al.* 2014) and more technical documents providing guidance to strategies for sustainable development in Vietnam (Hung *et al.* 2013; Trinh *et al.* 2013).

We also believe that our close consultation with local stakeholders helped to create a bottom up understanding of local stakeholders’ perceptions of ESS, and foster the incorporation of different types of knowledge in decision making processes (Lopez and Videira, 2016). This is crucial as changes in biodiversity and ecosystem services are strongest felt among local people who directly rely on these for their wellbeing and livelihoods. Our approach show how place-based research can help to capture local stakeholders’ opinions and preferences, as well as their attitudes towards ESS which should be an important part off environmental policies for sustainable agriculture/aquaculture development in the Mekong Delta (Quinn *et al.*, 2015; Berg *et al.* 2016).

In conclusion, our results show that rice, Pangasius catfish and shrimp farming relies and influence on many ESS in the Mekong Delta, and must be viewed in a broad context and not as isolated sectors. They are embedded in social-ecological linked systems and heavily dependent on ESS for their survival. Strategies for sus-

tainable food production must be directed towards methods that make use of the natural environment without severely or irreversibly degrading it. Local stakeholders should have an influence on how future agriculture system should be designed and managed and for whom. A sustainable development of agriculture and aquaculture must take into account the societal value of multiple ESS for an efficient and environmentally sound production of food. Otherwise there is a risk that short term gains, based on intensive ecosystem exploitations, will disrupt ESS of key importance to stakeholders’ livelihoods and wellbeing, potentially creating economic and social problems.

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