Climate-smart aquaculture:

Evidences and potentials for northern coastal area of Vietnam

Working Paper No. 169

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

Coastal aquaculture, particularly brackish water shrimp farming, plays an important role in the socio-economic development of most coastal communities on the North Central Coast (NCC) of Vietnam. However coastal aquaculture in the region is among the activities most affected by increasing global climate change, which threatens sustainable development of the fisheries sector, as well as food security of the country. Within the action plan framework for adaptation and mitigation for climate change in the Ministry of Agriculture and Rural Development and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), climate-smart aquaculture (CSA) trials have been conducted in Hoang Phong commune, Thanh Hoa province in 2015 by WorldFish, the Vietnam Institute of Economics and Planning (VIFEP) and Thanh Hoa Agriculture Extension Center (TEC). In the farm-level climate-smart aquaculture trials, tilapia was raised in rotation with tiger shrimp, mud-crab and seaweed in a traditional extensive aquaculture system. Initial results show that the aqua-smart practice under the CSA approach is a "triple win" for local aquaculture farmers through: (1) sustainably improving aquaculture productivity and farming efficiency of the current production system; (2) increasing adaptive capacity and resilience of coastal aquaculture to climate change; and (3) contributing to climate change mitigation. However, a number of constraints, such as lack of high quality fish seed and feeds, low market uptake for tilapia and uncertainty from extreme climate events, should be considered in scaling out the aqua-smart practice throughout the region.

Keywords

Coastal aquaculture; climate change; climate-smart agriculture; shrimp farming; climate-smart aquaculture

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Contents

Acronyms

CBA	Community-based adaptation
CSA	Climate-smart agriculture
CSAq	Climate-smart aquaculture
DARD	Department of Agriculture and Rural Development
FAO	Food and Agriculture Organization of United Nations
FCR	Feed conversion ratio
GHG	Greenhouse gas
MoNRE	Ministry of Natural Resources and Environment
HH	Household
NCC	Northern Central Coast
NTP-CC	National Target Program on Climate Change Adaptation
IPCC	Intergovernmental Panel on Climate Change
TEC	Thanh Hoa Agriculture Extension Center
VIFEP	Viet Nam Institute of Fisheries Economics and Planning
VND	Vietnamese Dong

Introduction

It is estimated that between 660 and 820 million people globally depend on fisheries[1] for their livelihoods and income. Of these, 58.3 million, including 84% of the people living in Asia, are directly engaged in the primary production (FAO 2014). The sector's contribution to food and nutrition security, gender equity and poverty reduction is increasingly recognized, particularly in developing countries. However, current patterns of increasing fish consumption and production imposes pressures on fisheries resources and ecosystem services. For the last 10 years, global production of capture fisheries has levelled around 90 million tonnes annually. This implies the need to increase aquaculture production to compensate for expected future shortages of fish for food. An analysis of future supply and demand for fish suggests that current levels of aquaculture production need to double in the next few decades to secure food and nutrition for the growing populations (World Bank 2013).

In addition, climate change is already largely hampering the global food production systems, including aquaculture (FAO 2014). The physical changes in climate, such as increase in temperature, variation in rainfall patterns, rise in sea level and increase in frequency and intensity of extreme climate events, have brought negative impacts on the physiological, ecological and operational processes in aquaculture (Handisyde *et al*. 2006; Daw *et al*. 2006; Badjeck *et al*. 2010).

Adapting to and mitigating the negative impacts of climate change require changes in aquaculture practices, farming community attitudes, as well as the locations of farming facilities. In view of resilience, adaptability and diversification of farmed species, it is argued that aquaculture will be able to respond appropriately to climate change impacts and emerge as an alternative livelihood (De Silva and Soto 2009). Furthermore, it has also been argued that increased production will have to come from simple farming technologies, which farmers can easily adopt, and involve both production of more low-priced food species and high-value species (Troell 2009).

The North Central Coast[2] (NCC) is among the poorest regions in Vietnam, where coastal aquaculture, dominated by extensive integrated farming systems, is one of the few livelihood options for poor coastal communities. In recent years, aquaculture in the region has experienced an increase in disease outbreaks and crop failures exacerbated by climate change. According to plausible scenarios for climate change and sea level rise for Viet Nam developed by the Ministry of Natural Resources and Environment (2012), the NCC has been severely affected by climate change, especially by rising temperatures and changing rainfall patterns. The maximum temperature has begun to exceed the tolerance limits of shrimp, the major farmed species,

[1] Indicating both capture fisheries and aquaculture

[2] Including six coastal provinces: Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri and Thua Thien Hue

negatively impacting their survival and growth rates. The increase in rainfall during the rainy season causes severe flooding; however the sharp decline in rainfall during the dry season also results in more difficulty in sustaining water supply for agriculture and aquaculture operations (VIFEP 2012).

Managing climate risks, while improving resource-use efficiency and productivity of coastal aquaculture, is therefore essential to meet food and nutrition security objectives. Preliminary research by the Vietnam Institute of Fisheries, Economics and Planning (VIFEP) (2013) in the coastal communes of Hoang Phong and Hoang Chau of Thanh Hoa province suggests that autonomous adaptation by local farmers via adopting traditional integrated aquaculture with species diversification can help farmers improve their productivity and household incomes, while also climate-proofing their livelihoods. In addition, incentive mechanisms and strategies, such as formal and informal micro-credit and group-based management institutions, can enhance the adaptive capacity and resilience of coastal aquaculture and farming communities to climate change.

This paper reports the initial results of integrated aquaculture practices of shrimp, mud crab and tilapia as a climate-smart agriculture (CSA) practice in Hoang Phong commune, Thanh Hoa province. It also discusses how the practice can address current challenges related to food security and climate change in aquaculture in the NCC.

Climate-smart agriculture approach and practices

It is widely accepted that agriculture[3] is particularly vulnerable to climate change. The impacts of climate change, compounded with increasing global demand for food, pose higher risks to livelihoods and food security, especially that of the world's poorest people (IPCC 2014). Agriculture, however, is also responsible for a large portion of greenhouse gas (GHG) emissions, as it is mostly driven by the extensive use of natural resources, such as deforesting forest lands, converting mangrove stands to aquaculture, or using fertilizers and energy inputs in agriculture production. This therefore requires the introduction of new inputs, techniques and services that can improve crop productivity without further degrading natural resources, such as soil and water, and the environment, while adapting to a changing climate and increasing resilience to risks from extreme weather events (Steenwerth *et al.* 2014).

The Food and Agriculture Organization of the United Nations (FAO) coined CSA in response to the intertwined global challenges of food insecurity, poverty and climate change. According to FAO (2013), CSA is "agriculture that sustainably increases productivity, enhances resilience, reduces/removes greenhouse gas emissions (GHGs), and enhances achievement of national food security and development goals" (Figure 1). This concept has been developed not only to simply

[3] FAO (2010) defines agriculture in the broader system of agriculture, fisheries and aquaculture, and forestry

focus on technologies or practices, but also to represent a set of strategies that can deal with climate change impacts by increasing resilience to weather extreme events, adapting to climate change and reducing GHG emissions. The CSA approach thus aims to improve the integration of agriculture development and climate responsiveness that supports sustainable and equitable transitions for agriculture systems and livelihoods across scales (i.e. ranging from the local to global) and time horizons (i.e. over short and long term) (Lipper *et al.* 2014; Steenwerth *et al.* 2014).

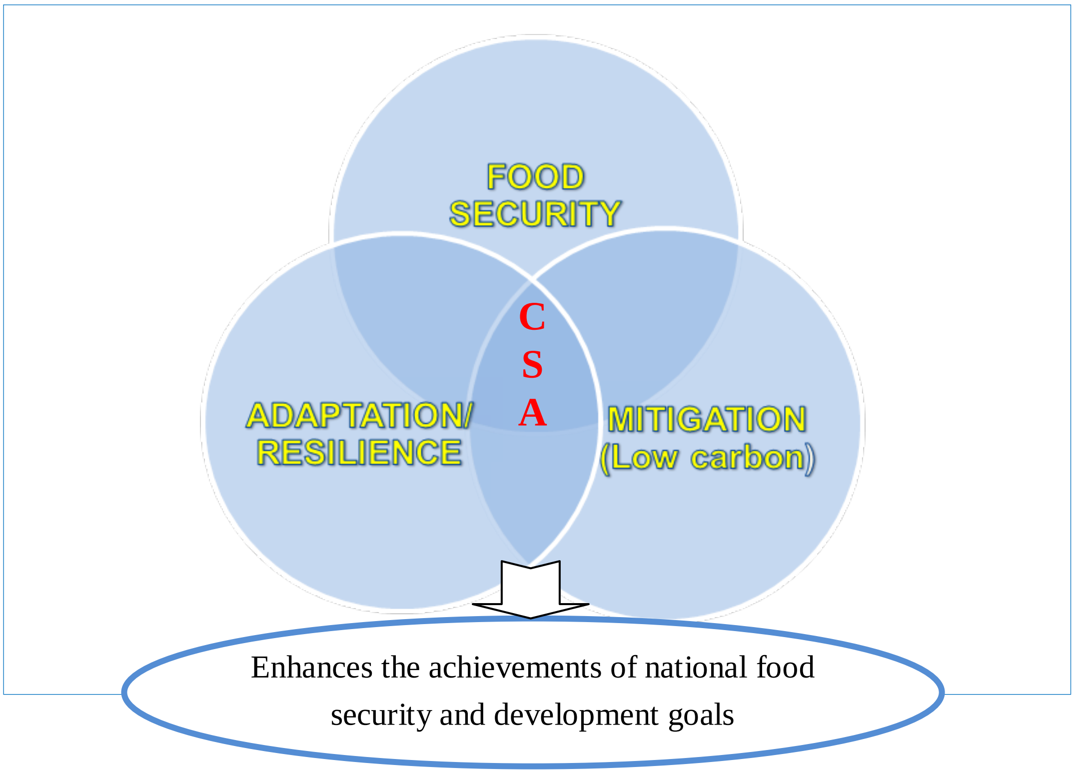


Figure 1. CSA approach as a base for national food security and development goals (Adapted from FAO 2013)

Although CSA emphasizes agricultural systems aiming to attain three objectives, it does not mean these objectives have to be met by every applied practice and/or in every location (FAO 2013; Lipper *et al.* 2014). The relative importance of each objective may vary across locations and/or situations, hence potential synergies and/or trade-offs will vary between and among the objectives. For example, in developing countries where food security and poverty reduction are of high priority, the focus will be more on stabilizing and sustainably increasing agriculture productivity, improving income and building adaptive capacity. In contrast, CSA approaches in developed countries may emphasize more on climate change mitigation through increasing production efficiency and reducing GHG emissions from agriculture (Lipper *et al.* 2014; Steenwerth *et al.* 2014). Therefore, achieving the targeted growth with a lower emission trajectory will require concerted efforts to maximize synergies and minimize trade-offs between productivity and mitigation (FAO 2013).

There are a number of climate-smart agricultural practices and investments that have been proven to significantly contribute to both climate change adaptation and GHG mitigation, including agroforestry, zero tillage, use of cover crops, intercropping, water conservation, water and nutrient investment and use of diverse varieties. Aquaculture technologies and practices that reduce energy consumption and optimize carbon sequestration also provide opportunities for mitigation (FAO 2013). For example integrated multitrophic aquaculture systems, which are not only less reliant or even non-reliant on fishmeal and fish oil inputs, but also utilize waste inputs from more intensive aquaculture, have higher potential for expansion than production systems that are dependent on capture fisheries commodities.

Recognizing the role of aquaculture as an important food production sector, FAO (2013) suggested three practical themes in developing various CSA strategies for the aquaculture sector:

(1) *Increasing sustainably production, yield and efficiency*: primarily focusing on intensifying production; using better integrated systems; improving stocks; making feeding more efficient and reducing losses from diseases;

(2) *Reducing vulnerability and increasing resilience*: improving farm site selection and design; individual/cluster insurance; using indigenous or non-reproducing stocks to minimize biodiversity impacts; improving efficacy of water usage; shifting from capture fisheries to coastal aquaculture; selecting for short-cycle production; improving water sharing; improving seed quality and efficiency; and

(3) *Reducing and removing GHGs*: primary options include integrated multitrophic aquaculture and better pond management.

Coastal aquaculture is the production of aquatic organisms in brackish and saline water, and is becoming increasingly popular in tropical countries (Troell 2009). This aquaculture system is highly diverse in practices and is dominated by integrated farming practices of multiple species (e.g. shrimp/prawn, mud crab, milkfish, seaweed, mussel and clam). The review by Troell (2009) shows that integrated aquaculture systems are dynamic, resilient and versatile, as their structure and function can change according to different locations, seasons, species and social environments. Among existing integrated aquaculture systems, polyculture is dominant (60%), with shrimp as the major species group being grown (76%), along with tilapia (29%) and milkfish (16%) (Troell 2009). The relationships between those cultivated species and their environmental systems largely depende on the biological characteristics of the species and the degree of farming intensification. In an extensive polyculture system mostly based on natural productivity, stocking aquatic species of different feeding habits together enables a more efficient utilization of pond resources. However, only a proper combination of ecologically different species at adequate densities will utilize the available resources efficiently, maximize the synergies between species and species-environment relationships and minimize the antagonistic ones.

In Asia, which contributess more than two thirds of the world aquaculture production, integrated coastal aquaculture systems have been practiced for centuries in Indonesia, China and Hong Kong, and more recently in the Philippines, Malaysia, Vietnam and Thailand (Troell 2009). In this system, most of the farms prioritize either shrimp (*P. monodon*, *P. vannamei*, *M. ensis*) or milkfish production. Crabs and other species are sometimes added as minor species for aeration, or added opportunistically if the market and environmental (i.e. salinity) conditions are favorable. According to Troell (2009), integrated aquaculture directly benefits farmers either through added value products, improved water quality, disease prevention, habitat conservation and greater allowed production volumes through waste reduction (emissions reduction). In the context of constrained inputs and resources (e.g., water, land, feed and energy), climate change and the need to address the negative environmental impacts from aquaculture, viable climate-smart aquaculture (aqua-smart) systems should be developed based on the most suitable techniques, and considering both traditional and more innovative practices.

ECO-SAMP project and climate-smart aquaculture trials

Project approach

In line with the national project “Assessment of climate change impacts on infrastructures, farming areas, productivity and production of coastal aquaculture in the North Central Coast region aiming to develop comprehensive adaptive measures and farm demonstrations those are able to adapt and mitigate to climate change ” funded by the National Target Program on Climate Change Adaptation (NTP-CC) from 2013 to 2015, the project "Enhancing community resilience to climate change by promoting smart aquaculture management practices along the coastal areas of North Central Vietnam (ECO-SAMP)" was designed to further support coastal aquaculture communities in the NCC in coping with climate change. Funded by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) in Southeast Asia and imlemented by WorldFish in collaboration with VIFEP and Thanh Hoa Extension Center (TEC), the project started in June and is scheduled to finish in December 2016.

Figure 2 presents the overall framework of the ECO-SAMP project approach from local to regional scales. Pilot activities under the project were implemented in Hoang Phong commune, Hoang Hoa district, Thanh Hoa province, which is on the NCC of Vietnam. The lessons learnt from the project will be scaled out and up to enhance community resilience and promote aqua-smart management practices and institutions in northern and north-central Vietnam.

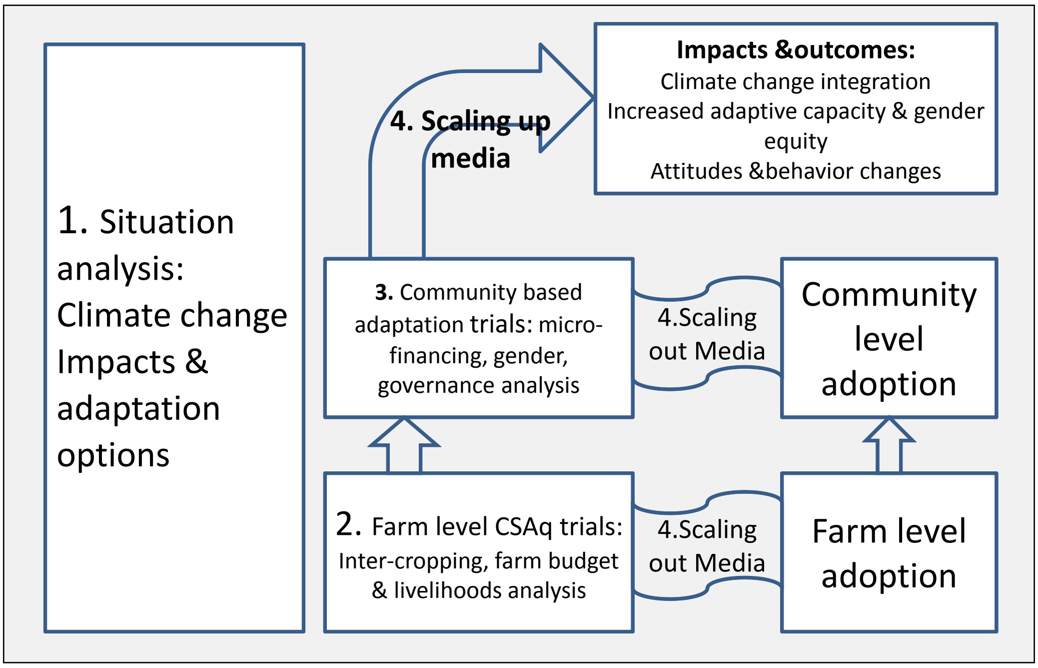


Figure 2. The ECO-SAMP project intervention framework

In partnership with WorldFish and TEC, VIFEP conducted a situational analysis related to climate change in the NCC region in June 2015. It focused on three main topics: (1) assessment of climate change and its potential impacts on coastal aquaculture, as well as livelihoods of coastal communities; (2) identification of promising climate resilient and adaptive options for coastal aquaculture systems; and (3) assessment of management and institutional mechanisms regarding sustainable coastal aquaculture management practices. The analysis was mainly based on existing information collected by the NTP-CC program. An additional study was also conducted through group discussions with local farmers in Thanh Hoa province. The results are not only key inputs for developing appropriate farm-level climate-smart aquaculture (CSAq)[4] practices and related supports, but also serve as a baseline for evaluating the project impacts.

The follow-up activity in 2015 was a CSAq trial, a key project intervention, at the farm level. The field trial was developed by WorldFish, VIFEP and TEC, in accordance with the results of the baseline study and farmers' perceptions of the CSAq intervention in the region. Local farmers were selected to test the CSAq practices on their farms with financial and technical support from the project. Participating farmers were trained by the project team on aquaculture management practices as well as business management skills, including farm budgeting and marketing, for successful adoption of the practice. In addition to providing support, the project also looked into improving resilience capacity for local farmers by promoting community-based adaptations

[4] We use "CSAq" here to avoid a confusing with "CSA-climate smart agriculture" in general.

(CBA). Under the CBA trials, micro-finance potentials, gender issues and community-based management and governance were also explored if these could be included in further interventions.

Since the CSAq trials were successful at the farm level in 2015, these practices will be scaled out throughout the NCC region in 2016. The technical guidelines for adopting the CSAq was developed based on the trial results and disseminated to local extension centres and farmers in the NCC's coastal provinces In 2016, capacity building and dissemination activities for scaling up will be conducted via training sessions, workshops and study tours. These, together with appropriate incentive mechanisms and management institutions, are expected to promote wider adoption of the tested CSAq practices. It is expected that about 1,000 local farmers in the NCC area would adopt and benefit from the practices that will enhance farmers' adaptive capacity and resilience to climate change by 2016.

Project site and CSAq trial

In accordance with the analysis results and the NTP-CC program, the ECO-SAMP project was implemented in Thanh Hoa province, which has the largest brackishwater area in the NCC region (7,700 ha or about 15.93% of the NCC's total brackish water aquaculture area). Brackishwater aquaculture in the province is concentrated in the coastal districts including Nga Son, Hoang Hoa, Quang Xuong, Tinh Gia and Nong Cong, with farmers growing diverse cultured species, such as shrimp (tiger shrimp, white leg shrimp, nipper shrimp), mud-crab, mollusks (clam, oyster), seaweed and brackishwater fish. Shrimp farming accounts for 87% (4,024 ha) of the total brackishwater aquaculture of the province, of which 97% is improved extensive production (Thanh Hoa DARD 2012). Hoang Hoa and Quang Xuong are major shrimp-growing districts, holding 38.1% and 18.4% of the total culture area respectively.

The project acivities were piloted in Hoang Phong commune, located in the southeastern area of Hoang Hoa district, Thanh Hoa province. About 90% (280 ha) of the aquaculture area in Hoang Phong is in brackishwater and half of this (140 ha) is located outside the sea dike. Brackishwater aquaculture is dominated by extensive polyculture systems in earthen ponds, accounting for about 80% of the total cultured area in the commune. Some of the more commonly stocked species are tiger shrimp (*P. monodon),* mud-crab (*Scylla sp.*), fish (e.g. seabass, sea mullet) and seaweed. This integrated aquaculture system features low stocking density and less use of inputs. The method was common in Vietnam during the beginning of the 1990s, however farming methods have only changed by a little, since local farmers started this practice. Despite the drastic changes in breeds being cultured, the weather and availability of natural resources, local people still apply traditional farming methods. Annual production of brackishwater aquaculture in Hoang Phong is estimated at around 410 tons, of which seaweed accounts for 80% of the total production. Although tiger shrimp is considered as the major cultured species in the system, the yield of shrimp is quite low (ranging from about 50 to 300 kg/ha/year), compared to more intensive monoculture systems in the Red River and Mekong River Deltas.

Vietnam, and the NCC of Vietnam in particular, have been experiencing climate change for the last 50 years based on meteorological observations. Recent changes in climate have brought about negative impacts on the coastal aquaculture system in Hoang Phong. Climate data shows rainfall patterns in Thanh Hoa have changed by a decrease in frequency, but an increase in intensity (VIFEP 2013). This resulted in great fluctuations in pond water environment (i.e. salinity, pH). Further with ‘Tieu Man’ flooding frequently occurred in June, pond salinity sharply decreased and dropped to the lowest level (about 2-3%) during the September-October period (Figure 3). The low salinity means shrimps and mud-crabs are more vulnerable during this period.

Increasing temperature and high variations between day and night temperatures also cause shocks to cultured species, thus increasing risks of crop failure, particularly in environmentally sensitive species such as shrimp. Leaving the pond empty during the ‘Tieu Man’ period is the current solution and response of most farmers in Hoang Phong to minimize their risks. This adaptation solution however results in a reduction of the farmers’ income. Therefore there is a need to find suitable cultured species and/or farming practices that can help local farmers adapt to climate change, reduce production risks, while sustainably increasing their income.

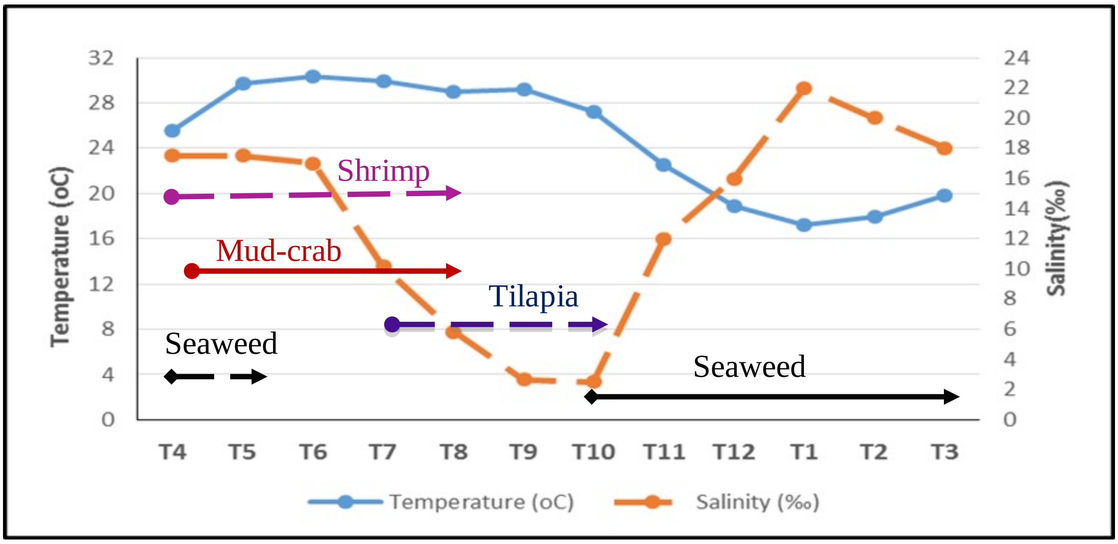


Figure 3. Fluctuations in pond salinity and temperature in Hoang Phong area

After initial screening of possible farmed species (e.g., tilapia, seabass, goby, mullet) the project team concluded that introducing mono-sex tilapia into the traditional aquaculture system during the rainy season from July to October in Hoang Phong seemed to be the most feasible solution as a CSAq practice. This intervention promotes diversification of cultured species, improves farming productivity and lowers risks from climate change. This was re-assessed by local farmers using the Analytic Hierarchy Process (AHP) using a number of criteria: (1) suitability with local environmental conditions; (2) production economic efficiency; (3) market potential; and (4) investment requirement (see annex 1 for the result). Once tilapia had been chosen as the species to be introduced, five local households were selected to conduct the trial on their own farms with financial and technical support from the ECO-SAMP project. Costs of fingerlings and 30% of the feed costs for testing the practices, or an average amount of $1,000 per household, were subsidized by the ECO-SAMP project.

Table 1 shows the technical details of the CSAq trial for different salinity levels. Regarding the tilapia crop, three farm trials were set up in high salinity areas (4-22% salinity), with an average size of 1 ha. These farms cultured tiger shrimp with other species, like mud-crab, seaweed and natural fishes in an integrated and/or rotation system. two of the farm trials were in low salinity locations (1-10% salinity) with an average pond size of 0.5 ha. Due to the low salinity, farmers could not grow seaweed, and often integrated only shrimp and mud-crab.

Table 1. Technical integration of the CSAq in Hoang Phong

Species	Culture period	Stocking density (ind./m^2)	Stocking size (gram/ind.)
Tiger shrimp	Apr.- Aug.	5-7	PL_{15}
Mud crab	Mid Apr.- Aug.	0,1	10
Tilapia	Jul. – Oct.	0.3-0.6	10
Seaweed	Oct-Jul (next year)	-	-

Ponds were stocked with tilapia at the end of shrimp crop in June 2015. Fingerlings were nursed for 20 days in a small pond before being released into the trial ponds. This aimed to improve the survival rate of tilapia. The stocking density of tilapia was diffent from the two types of CSAq trials, as the ponds in the high salinity areas were stocked with 0.3 individual/m^2, while the ponds in low salinity area had 0.6 individual/m^2.

Aside from providing tilapia seed and feed to the trial farms, technical support was provided to the participating farmers as well as cooperative members. A series of training activities before and during the CSAq trial was held. These included technical training sessions on culture techniques of tilapia in brackishwater, integrated farming techniques, disease prevention and treatment, sessions on farm management skills, including farm budgeting and marketing and a study tour to see other brackishwater cultures of tilapia in the neighbouring coastal province of Nam Dinh.

In addition, trials on community-based adaptation were also implemented to improve adaptive capacity and resilience of the Hoang Phong community in general, and the aquaculture cooperative in particular. The main objective of the community-level trial is to improve collective actions of farming communities. Two meetings with the management board and the four community groups of the cooperative were held to consolidate cooperative regulations as well as to discuss the potential for upscaling the CSAq practices in the next year's crop.

Gender issues were also assessed to explore gender roles in scaling up the tested CSAq practices in other aquaculture communities. Two community group meetings were organized for women farmers to discuss: (1) women's participation in decision- making and farming activities in the household; (2) women's roles in micro-credit systems (informal, semi-informal and formal) in the locality.

Results and Discussion

Participating household profiles

A brief profile of the CSAq trial households is given in Table 2. The average household size is about four people, with two of them counted as part of the labour force. This figure indicates a similar dependency ratio to that of the whole commune.

Land is the main production asset and varies among households in the Hoang Phong commune. Among the trial households, land size ranges from 0.7 to 1.4 hectares, of which aquaculture land accounts for 81.86% of the total household land. The differences in land size can be explained by the age of the household, as the older households usually have larger land assets.

In accordance with land ownership, the household's livelihoods are diverse, with the three main activities of agriculture (rice and vegetable crops), aquaculture and livestock rearing. The annual average income of the trial households is around VND87 million (USD 3,909)[5]. Aquaculture remains a major source of the household income, accounting for 80% of income. This means that improving aquaculture plays an important role for increasing income and improving the household's well-being.

Table 2. The CSAQ trailed households' profile

Household (HH)	HH Size (peo.)	Fulltime labour (peo.)		Land condition (m2)		Livestock (head)				Total income (mill/HH /year
		Agri	Aqua	Crop	Aqua	Pig	Chicken	Duck	Cow	
Truong Van Mien	4	1	1	3,000	10,000	20	50-60	25-30	1	100
Trương Tien Sy	4	1	1	2,000	12,000		20-30	10		85
Truong Van Nuong	3	1	1	2,500	10,000	5	30-50			60
Luong Huu Hoan	5	1	1	2,500	5,000	50	150-200	150-200	1	120
Luong Duy Phuong	2	1	1	-	7,000	45	120	50-80		65-70

Source: Farm trial monitoring records

CSAq trial results

The results of the CSAq trial of integrating mono-sex tilapia into traditional aquaculture system in Hoang Phong are given in Tables 3 and 4. In general, tilapia grew well in all tested farms. After four months, the harvested tilapia had an average market size of 650 gram/fish, and varied from 500 to 700 gram/individual. In consideration of market uptake and size of tilapia, the harvest was divided into two or three times depending on the trial household. This practice ensures a good price for their harvest. The average productivity of the total farm harvest in low salinity areas was 3.1 tons per hectare, two times higher than that of higher salinity farms (1.3 tonnes/ha). This productivity difference could be mainly explained by differences in stocking density as the low salinity farms had double the stock density of the high salinity farms. Another reason could be that the salinity shock in high salinity farm ponds at the time of stocking led to

[5] USD 1 = VND 22,555

the death of about 10% of fingerlings stocked. It is thus suggested that farmers do salinity acclimatization of tilapia before stocking them in high salinity farm ponds.

Even though the low salinity farms had higher yields, their average food conversion ratio (0.96 FCR) was double that of the high salinity farms (0.45 FCR). This suggests that low salinity farms highly depend on artificial pellet feed sources, which reduces economic efficiency.

Table 3. Feed conversion ratio (FCR) and productivity of the CSAq practices

Species	Harvesting size	FCR		Yield (kg ha^{-1})	
		High salinity, low stocking density	Low salinity, High stocking density	High salinity, low stocking density	Low salinity, high stocking density
Tiger shrimp	30-35 ind./kg	-	-	124	285
Mud crab	3-4 ind./kg	-	-	126	70
Tilapia	0.65kg/con	0.446	0.962	1,293	3,100
Seaweed	-	-	-	8,500	-

The productivities of shrimp and mud-crab were not affected by tilapia integration as these two species were stocked in April before the project intervention. It should be noted however, that stocking of tilapia had positive effects on seaweed growth. Tilapia helps clear the wild mosses[6] that compete with seaweed growth. The average yield of seaweed of 8.5 tonnes/ha increased by about 30% from the previous year (6.5 tonnes/ha).

In terms of economic efficiency, Table 4 shows the details of cost-benefit analysis of the CSAq trials. On average, the net income earned from the trial was about VND 73 million/ha/household (USD 3,280), and tilapia contributed 28.8 - 35.2% to the total aquaculture income of household. It should be noted that the calculated cost-benefit does not incorporate a reduction of costs for removing wild mosses. The participating farmers estimate the cost reduction for removing the moss to be around VND 6 to 7 million/ha/year.

A comparison of the different trials shows the net income of the high salinity farms was 1.6 times higher than that from the low salinity farms, as the high salinity farming systems had an additional income from seaweed. Another reason is the higher economic efficiency of the high salinity farms due to a lower FCR and the use of available natural feed sources. This is presented through the benefit-cost ratio (B/C) given in Table 4.

[6] small flowerless plants that typically grow in dense green clumps or mats, often in damp or shady locations

Table 4: Cost-benefit analysis of the CSAq trials (VND thousand/ha/year)

	Shrimp, mud-crab, seaweed and tilapia (n=3; high salinity; lower tilapia stocking dens.)	Shrimp, mud-crab and tilapia (n=2; low salinity; higher tilapia stocking dens.)	**Total average**
	Mean	Mean	Mean
Total costs	**41,132**	**49,380**	**44,431**
- *Feed share (%)*	29.87	49.27	38.50
Total gross revenues	**127,868**	**101,500**	**117,321**
- *Tilapia share (%)*	33.34	45.81	37.66
Total benefits	**86,737**	**52,120**	**72,890**
B/C ratio	2.11	1.06	1.64

As an omnivorous species, tilapia can feed on organic detritus and wastes, thus helping to reduce significant amounts of excess nutrients, improving water quality for shrimps. This also promotes production diversification. The integrated culture of shrimp and tilapia has been practiced in several countries such as Ecuador, Thailand, Philippines and Indonesia. It is estimated that such cultures in Ecuador increased shrimp harvest size by 18% and total production by 13-17%, and lowered FCR by 15% (Troell 2009).

Implication on livelihoods and food security. The NCC is among the poorest regions of Vietnam. In 2014, the rate of households at poverty line and marginalized poverty line were about 12.22% and 8.58%, respectively (MOLISA 2014)[7]. Coastal aquaculture is an important livelihood for most coastal households in the region. This implies that sustainable development of the coastal aquaculture system is crucial in achieving food security, especially with the pressures from the growing population and increasing climate change. Successful integration of mono-sex tilapia contributes to production gains alongside poverty reduction through improved contribution to income sources (14.23-42.86% of the total household incomes). Tilapia production also provides local people with better access to fish for food and nutrition.

Implication on climate change resilience. The introduction of tilapia has improved resilience of coastal aquaculture systems through diversification of cultured species. This can both increase the efficiency of the system and build their resilience to climate change. It can spread risk and increase economic resilience at the farm and local community levels. Tilapia crops can serve as "risk insurance" for households experiencing shrimp crop failures due to climate change. Additionally, tilapia also improves pond environments as it is a "filter-feeder" that reduces risk of disease outbreak in the shrimp.

Implication for low carbon aquaculture practices. The rapid development of intensive and semi-intensive fed aquaculture systems, such as shrimp and finfish, aim to meet growing demand, but these are often associated with negative environmental issues. One of the main environmental

7 According to Circular 09/2011/QĐ-TTg: household at poverty line or marginalized poverty line is the one with average income below VND4.8 mill./person/year or from VND4.812-6.024mill./person/year.

problems is the discharge of significant nutrient loads from open water systems and effluents from land-based systems into coastal waters. Improved energy efficiency and decreased use of fish meal and fish oil feeds are essential mitigation strategies. The integrated coastal aquaculture system of shrimp, mud-crab, seaweed and tilapia makes use of available natural feed sources and wastes. This thus significantly reduces the use of industrial feed, which is one of the main contributors to the carbon footprint of aquaculture systems.

Community-based CSAq scaling out and barriers to adoption

A meeting among the aquaculture cooperative members was organized at the end of tilapia crop. The main focus of the meeting was to assess the CSAq trials and potentials for wider adoption of the CSAq practices in the community. Most farmers who attended the meeting expressed their willingness to adopt the practices. Apart from increasing household income, adding tilapia also improves pond environments, and indirectly contributes to increased production efficiency of the household's farming system.

However, a number of barriers for community based CSAq scaling out have been mentioned by the local farmers:

(1) Lack of seed and feed source of good quality is a major constraint that limits the adoption of the CSAq in the community.

(2) The current low market uptake for tilapia would result in a lower adoption rate of the CSAq practice.

(3) Increased uncertainty of extreme climate events also lower farmers' incentives to invest in new techniques and practices.

Conclusions and policy implications

Climate change is threatening coastal aquaculture production systems in the NCC region of Vietnam. Finding an appropriate approach to transform production systems is crucial for ensuring food and nutrition security while reducing GHG emissions. Developing CSAq practices by integrating mono-sex tilapia into traditional integrated maricuture systems has proven to be a feasible option.

The results from trials in Hoang Phong commune in Thanh Hoa province show that incorporating tilapia is a good climate change adaptation strategy, as it contributes significantly to all three CSA objectives. Stocking tilapia resulted in higher productivity and production efficiency, leading to a significant increase in household income by 14.23-42.86%. A diverse product portfolio also increases the resilience of the system when faced with changing prices or crop failure due to climate change and disease outbreaks. By utilizing natural feed sources and excessive nutrients in the farming ponds, the use of pellet feed for tilapia is reduced, resulting in lower GHGs emissions.

The promotion and scaling-up of the CSAq, however, requires supporting policies and institutions. A key factor driving adoption of tilapia integration into coastal aquaculture systems in the NCC is the market uptake. A higher rate of adoption means larger production of tilapia. Therefore, support in expanding the market for tilapia, especially the export market, will encourage the up-scaling of the integrated coastal aquaculture practice throughout the region. Other issues such as low quality fingerlings and high feed costs are also barriers to scaling up the CSAq practice. Building the linkage between feed and seed suppliers and farmers' groups should be an appropriate solution.

References

Badjeck M C, Allison E, Halls A, Dulvy N. 2010. Impacts of climate variability and change on fisherybased livelihoods. *Marine Policy* 34: 375–383.

Daw T, Adger W N, Brown K, Badjeck M C. 2009. Climate change and capture fisheries: potential impacts, adaptation and mitigation. In Cochrane K, De Young C, Soto D, Bahri T (eds.). *Climate change implications for fisheries and aquaculture: Overview of current scientific knowledge. Fisheries and Aquaculture Technical Paper* 530: 107–150. Available at: www.fao.org/docrep/012/i0994e/i0994e00.htm)

De Silva S S. and Soto, D. 2009. Climate change and aquaculture: potential impacts, adaptation and mitigation. In Cochrane K, De Young C, Soto D, Bahri T (eds.). *Climate change implications for fisheries and aquaculture: Overview of current scientific knowledge. Fisheries and Aquaculture Technical Paper* 530: 151-212.

FAO. 2014. Statistical Yearbook. Asia and the Pacific Food and Agriculture. Bangkok: FAO.

FAO. 2014. Climate Change Adaptation in Fisheries and Aquaculture. Compilation of Initial Examples. Rome: FAO.

FAO. 2013. Climate-Smart Agriculture Sourcebook. Rome: FAO.

FAO. 2014. Energy-smart. Rome: FAO.

FAO. 2014: Success stories on climate smart agriculture. Rome: FAO.

FAO. 2011. “Energy – Smart” Food for People and Climate: Issue Paper. Rome: FAO.

Handisyde N T , Ross L G, Badject M C, Allison E H, 2006. The effects of climate change on World Aquaculture: A global perspective. Final Technical Report, DFID Aquaculture and Fish Genetics Research Programme. Stirling, UK. Available at www.aqua.stir.ac.uk/GISAP/pdfs/Climate_full.pdf.

IPCC. 2014. 2014 Climate change synthesis report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.

Lipper L, Thornton P, Campbell B M, Baedeke T, Braimoh A, Bwalya M, Caron, P., Cattaneo A, Garrity D., Henry K., Hottle R., Jackson L., Jarvis A., Kossam F, Mann W, McCarthy N, Meybeck A, Neufeldt H, Remington T , Sen P T, Sessa R, Shula R, Tibu A. Torquebiau E F. 2014. Climate-smart agriculture for food security. *Nature Climate Change* 4: 1068-1072. Access online at: www.nature.com/natureclimatechange.

Lobell, D B, Schlenker W, Costa-Roberts J. 2011. Climate trends and global crop production since 1980. *Science* 333: 616–620.

Ministry of Labour, Invalids and Social Affairs (MOLISA). 2014. National Report on Results of Hunger Eradication and Poverty Alleviation program. Ha Noi: MOLISA.

Ministry of Environment and Natural Resources (MONRE). 2012. Scenarios for Climate Change and Sea Level Rise for Viet Nam. Ha Noi: The Natural Resources, Environment and Mapping Publishing House.

Steenwerth K L, Amanda K H, Arnold J B, Michael R C, Andrea C, Colin J C, Jerry L H, Kevin H, Jan W H, William R H, Bryan M J, Ermias K, Rik L, Leslie L, Mark N L, Siwa M, Ravi P, Matthew P R, Samuel S S, William M S, Michael S, Pablo T, Stephen M W , Sonja J V, Eva K W, Lovell S J, Louise E J. 2014. Climate-smart agriculture global research agenda: scientific basis for action. *Agriculture & Food Security* 3:11. Access online at: http://www.agricultureandfoodsecurity.com/content/3/1/11

Department of Agriculture and Rural Development (DARD). 2012. Annual report on provincial production of Agriculture, Forestry and Fisheries. Thanhhoa: DARD.

Troell M. 2009. Integrated marine and brackishwater aquaculture in tropical regions: research, implementation and prospects. In Soto D (eds.). *Integrated mariculture: a global review. FAO Fisheries and Aquaculture Technical Paper* 529: 47–131.

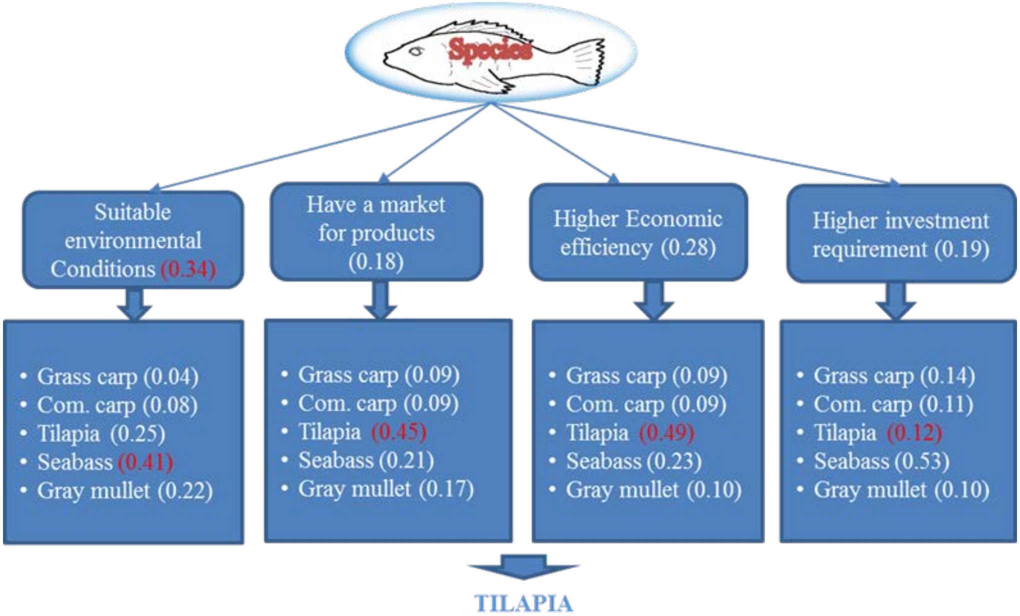
Vietnam Institute for Fisheries Economics and Planning (VIFEP). 2012. Report on assessment of vulnerability to climate change in impacted areas for developing effective policies and interventions. National Target Program on Climate Change Adaptation Code: 0356. Hanoi: VIFEP.

Vietnam Institute for Fisheries Economics and Planning (VIFEP). 2013. Viet Nam’s Master Plan for Fisheries Development to 2020, vision 2030: Ministry of Agriculture and Rural Development. Hanoi: VIFEP.

World Bank. 2013. Fish to 2030: Prospects for fisheries and Aquaculture. Report No. 83117-GLB. Washington DC: WorldBank. 102 p.

Appendix 1

Species selection for the integrated coastal aquaculture system using AHP approach



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