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IMPROVING PROFITABILITY OF INTEGRATED RICE-SHRIMP FARMING IN BRACKISH AREA: A CASE STUDY OF MEKONG DELTA, VIETNAM

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ABSTRACT

Rotation between rice and shrimp farming by way of filter ponds and diversification of farm activities was studied with the aims of testing the efficiency of filter ponds and evaluating the combination of incorporating the growing of upland-crops on dikes of rice fields. Three groups of farmers participated in study trials which were the pilot group used a filter pond and applied new methods, the control group had a filter pond and applied the recommended new methods, and the normal practice (control) group not having a filter pond. Results showed that the rice-shrimp farming system using a filter pond improved water quality (pH, alkalinity and salinity) and reduced input costs. Growing upland crops on the dikes had a high financial return; though for both vegetables and the grass for the dairy cows will strongly depend on the market. On one hectare of land, farmers using a filter pond for rice-shrimp farming combined with upland-crops had a higher economic return than the traditional rice-shrimp farming system (2,812 compared with 854 USD/ha/year). However, implementing this model requires farmers to build filter ponds to aid freshwater storage, proper management skills and family labour resources. Diversification of farm activities such as integrated rice-shrimp culture may be a strategy for farmers for adapting to the impacts of climate change such as extreme weather events, less rain and saltwater intrusion.

KEYWORDS: Filter pond; financial return; rice-shrimp farming; upland-crop

INTRODUCTION

The Mekong Delta region, in the South of Vietnam faces four major threats including sea level rise (Van *et al*., 2012; Fujisawa & Kobayashi, 2013; Smajgl *et al.,* 2015), land subsidence (Fujisawa & Kobayashi, 2011; Erban, Gorelick & Zebker, 2014), reduced fresh water flow (Mertz *et al.,* 2008) and salinity intrusion (Duyen *et al.,* 2015; Smajgl *et al.,* 2015). Land subsidence is primarily due to groundwater use and excavations for flood prevention dike construction (Erban, Gorelick & Zebker, 2014; Huynh *et al.*, 2016). Taken all together, these threats have impact on fresh water and saline water availability (Van *et al*., 2012). Soc Trang is one of the provinces within the Mekong Delta brackish water area, where rain water is used in a rice-shrimp rotational farming system. This integrated farming system has played an important role in the economy of these brackish water areas (Tran Thanh Be *et al*., 2003). However, farmers are losing interest in this system due to changing water quality and climate change related issues such as greater temperature fluctuations, limited freshwater supplies in the dry season, excessive flooding in the rainy season, and saline water intrusion that is affecting the income of farmers. Diversification in rice-shrimp farming system might stablize farm income and provide other livelihood opportunities in the coastal areas (Ha *et al*., 2013; Olivier, 2018). Several solutions have been designed to adapt to the changing weather conditions in the future (Dung *et al*., 2012; 2017). One of the solutions is to use filter ponds to supplement rice-shrimp farming system combining with growing vegetable in dikes, and to stock some kinds of tilapia fish at low density in the shrimp ponds to improve the water quality (Nguyen & An, 2016). The overall objective of this trial was to improve rice-shrimp farming system and improve storage and utilization of rain water for growing upland crops, with the following specific objectives: (1) to assess effectiveness of filter ponds combining Nile tilapia into the traditional rice-shrimp farming system; and (2) to use rain water effectively to plant upland-crops on pond dikes.

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MATERIALS AND METHODS

Location and condition of the study

The My Xuyen district is located in a brackish water zone of Soc Trang Province, the interface between the freshwater and the saline water zones (Figure 1). Water courses in the district are affected by saline water from the sea for about 6 months in the dry season. Major farming activities in the district are rice and shrimp production, which accounts for 89% of the aquaculture production. In the rice-shrimp rotation system, farmers grow one rice crop, which totally relies on rainfall followed by rotation with shrimp culture using saline water from the sea in the dry season.

A case study in Hoa Tu 1 commune, My Xuyen district, most local farmers rotate crops between rice and tiger shrimp (*Penaeus monodon*). Rice cultivation takes about 4.5 - 5.0 months, followed by one to two months of pond preparation before stocking tiger shrimp for a 5 – 6 months production cycle. The stocking density for tiger shrimp culture is 6 individuals per m^2. The tiger shrimp are not fed, and the ponds are limed (CaO, $CaCO_3$, $CaMg(CO_3)_2$). Ponds are fertilized with inorganic N and P fertilizers. Recently, farmers were allowed to introduce Pacific white-leg shrimp (*Penaeus vannamei*), but the stocking density remaining less than 35 PL/m^2. These shrimps are fed a commercial shrimp diet. The ponds have paddlewheel aerators, with a goal of producing one crop of white-leg shrimp (2.5 months) and one crop of tiger shrimp (5 months).

The main water-related problems in the study site are poor water quality for shrimp, due to pollution of the freshwater supply source and high temperature of pond water in the hotter days of the dry season. Moreover, the salinity changes during the transition between dry and wet seasons has been proved to be a stressor for the shrimp (Van *et al.*, 2012; Duyen *et al.,* 2015). Rice is grown in the rainy season, followed by tiger shrimp in the dry season and then shifting to white-leg shrimp culture. The highest salinity reached in the ponds is around 20 ppm, but it is most frequently much lower. This is a tricky farming system, because the rains do not come each year at exactly the same time. With this farming system the time management is critical. The system might quickly shift to mainly shrimp production if farmers allow for (even low) saline conditions over longer periods of the year.

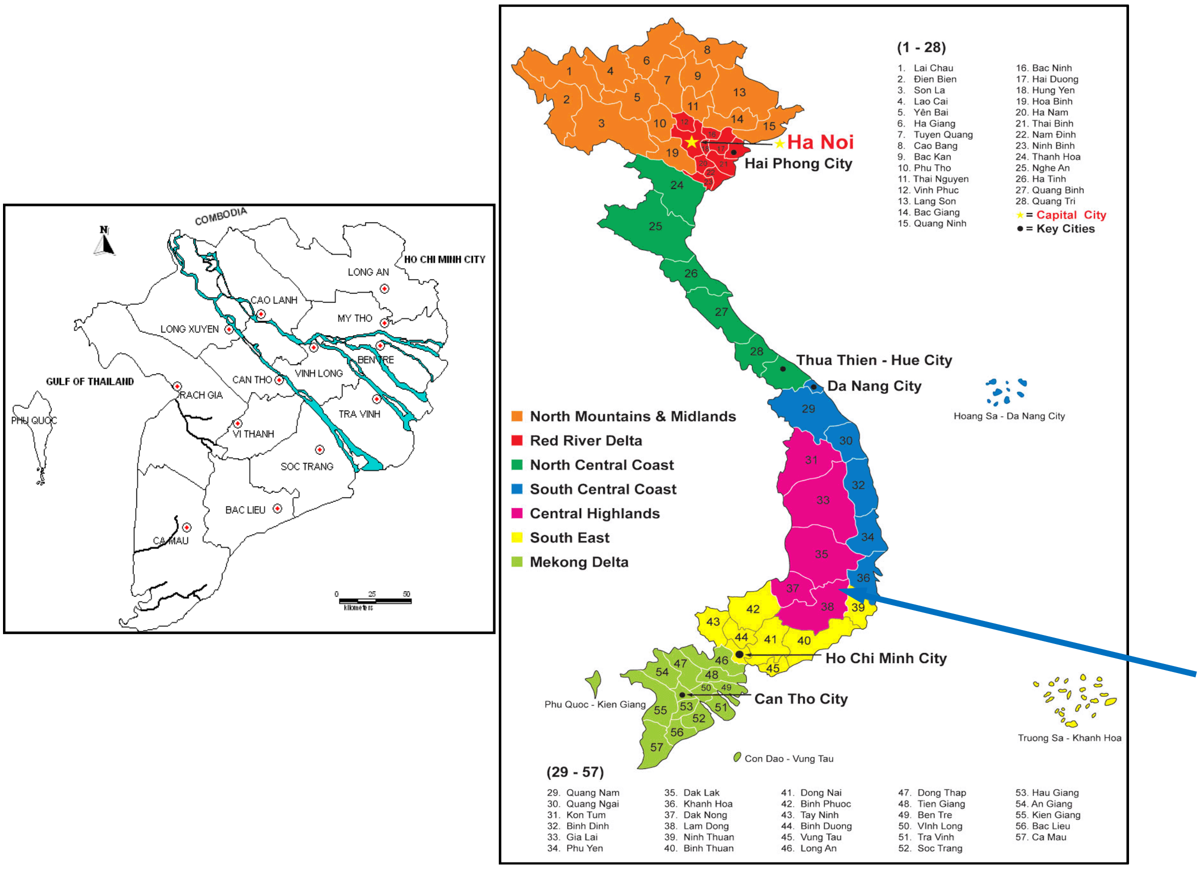

Figure 1. Study areas of the Mekong Delta, Vietnam.

Trials in farmers' fields

Due to the seasonal farming calendar of crops and aquaculture, the pilot trials ran over a full year cycle, starting in March 2019, and subsequently completed in March 2020. Three groups of farmers were selected for testing, monitoring and evaluating of the new methods. The first group was the pilot ponds consisting of 6 farms having a filter pond area and applying the new methods. New methods applied for the first group were raised tiger shrimp (*Penaeus monodon*) with low stocking density and used a filter pond in the dry season. The filter ponds were used to store and treat water before being supplied into shrimp farming, and these filter ponds occupied about 15-20% of the shrimp farming area. In the filter pond, farmers stocked Nile tilapia (*Oreochromis niloticus*) at low density (one fish/10 m^3 of water) to improve the quality of the inlet water for the shrimp. The filter ponds were also utilized for raising white-leg shrimp (*Penaeus vannamei*) after finishing its function of supplying water for only one during the tiger shrimp farming. On the dikes of ponds for this first group, farmers grew various upland-crops (e.g. taro, sorghum and vegetables). The second group was as control ponds comprising of 6 farms, that had a filter pond and applied the recommended methods from the pilot; tested the feasibility of filter ponds; raised tiger shrimp at low stocking densities and used a filter pond for raising white-leg shrimp similar to first group. The third group was normal practice group also consisting of 6 farms, without a filter pond and applied the common shrimp farming practices. This third group practised the traditional dry season tiger shrimp farming. All groups conducted normal rice farming in the wet season.

Common cropping patterns of farmers in the study sites are tiger shrimp farming in the dry season from March to August and rice culture in the wet season from September to January in following year. In the present trial slight modification was made for the rice-shrimp farming system where farmers raised tiger shrimp from March to September, and sowed rice in the wet season from September to January. The rice-shrimp farming system with a filter pond was used to provide water for the shrimp pond in the dry season and to raise white-leg shrimp during the farming season (Figure 2). The filter ponds were stocked with Nile tilapia from March to June, and then they were used to raise white-leg shrimp. On the dikes, farmers planted vegetables (from June to December), or alternatively, all year around depending upon their preferences.

Data collection and analysis

In all groups, water quality data in filter ponds, shrimp fields and canals were collected every two weeks including pH level, alkalinity and salinity from seeding to harvest. The input costs for shrimp farming and other farm operations were accessed every week. Yields of rice, shrimp, biomass and economic return were calculated at the end of the harvest. Soil analysis was implemented before sowing at a depth of 0-20 cm and 20-30 cm to test pH and salinity suitable for rice sowing and shrimp farming later on. The soil on the dikes was also analysed for pH, salinity, N, P, K and organic matter before, during and after sowing. The productivity of crops, input costs and economic return were assessed at the end of the farm trials. Statistical analyses were performed using two-way ANOVA with Tukey's post hoc test for significant differences at a minimum 95% confidence level.

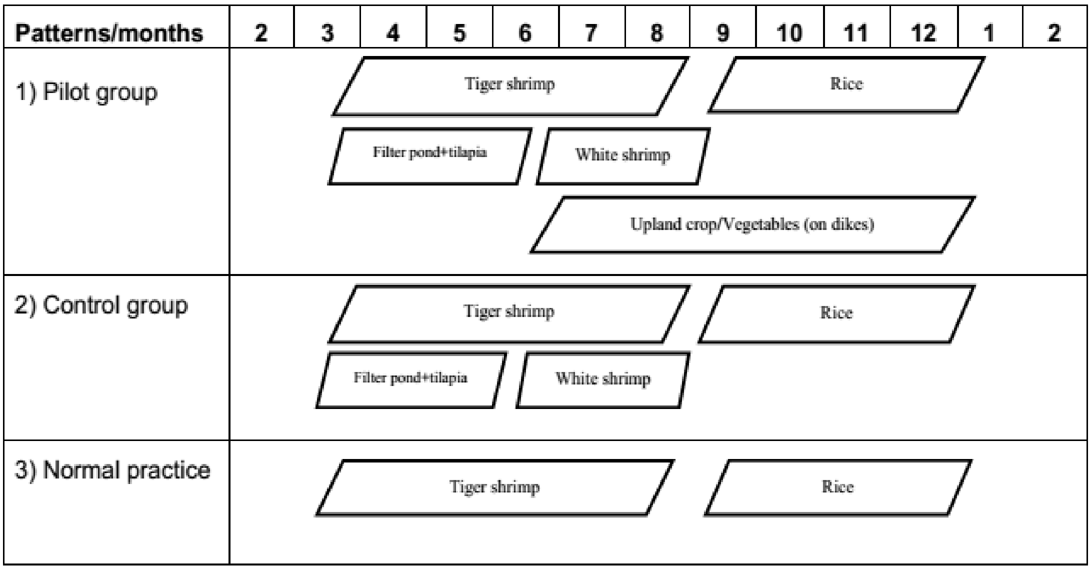

Figure 2. Seasonal calendar of common practice and farm trials in Hoa Tu 1 commune, My Xuyen district, Soc Trang province.

RESULTS AND DISCUSSION

Human resources

Mean number of households in the study area are 4.3 persons. This is in line in comparison to the average number of household members in the entire Mekong Delta Region of about 4 persons/household. The labour force in the family generally focusses on agricultural activities (2.7 persons/household); labour use for non-agricultural activities is very low (0.5 person/ household). The labour force among households did not differ among the three experimental groups.

Land resources

The total farm land area of the pilot farmer group is larger than the control and normal farmers groups (Table 1). In particular, land for cultivation is highest in pilot farmer group (1.51 ha/household) and lower in control and normal farmer group (0.9 and 0.76 ha, respectively). In the pilot and control group, farmers used about 20-25% of the cultivated land (approximately 0.1 to 0.3 ha) to dig a filter pond to supply water for shrimp pond, so the shrimp farming area in these groups are higher than normal farmer group who do not have a filter pond. In the farm land area, farmers use between 46 to 55% of the area for rice cultivation, 14 to 31% of ditch area and 18 to 31% of dike area. On the dike area farmers grew vegetables and upland-crops. This result indicated that farmers need a large area of land to dig a filter pond to supply water shrimp for pond.

Role of filter ponds

Improving water quality of shrimp pond

The filter pond has an important role in improving water quality for the shrimp pond. Results showed that the water pH in shrimp pond at pilot and control farms ranges 7.5 to 8.3, that were higher than normal farmers group. Similarly, water alkalinity ranged from 70-117 and salinity from 2.0 to 7.7 ppt in shrimp pond were higher than farmers engaged in normal practices due to water storage and improved water treatment for delivery to the shrimp pond (Table 2, 3

Table 1. Land resources (ha) of the rice-shrimp system in Hoa Tu 1 commune, My Xuyen district

Items	Pilot group	Control group	Normal practice	Significance
1) Farm size area	1.66 ± 0.31[a]	1.07 ± 0.12[b]	0.91 ± 0.12[b]	*
2) Farming area	1.51[a]	0.90[b]	0.76[b]	*
- Filter pond area	0.30[a] (24.5%)	0.14[b] (20.6%)	0.0 (0%)	**
- Rice area	0.62[a] (52.6%)	0.42[a] (54.6%)	0.32[a] (45.7%)	ns
- Ditch area	0.38[a] (29.8%)	0.12[a] (14.7%)	0.26[a] (30.9%)	ns
- Dike area	0.20[a] (17.6%)	0.23[a] (30.7%)	0.18[a] (23.4%)	ns

Tukey's significance: ns ($P \geq 0.05$); * ($P < 0.05$); ** ($P < 0.01$) for each colum followed with the same letter (a, b or c) do not differ at 5% significance level.

Table 2. Water pH in shrimp pond by farmer groups at the sampling dates in Hoa Tu 1 commune, My Xuyen district

Group	Mar.30	Apr.15	Apr.30	May 15	May 30	Jun.15	Jun.30	Jul.15	Jul.30
Pilot group	8.28[a]	7.90	7.66	7.70	7.54[b]	7.50[b]	7.60[b]	7.50[b]	7.60[a]
Control group	8.00[ab]	8.02	7.93	7.95	7.93[a]	7.86[a]	7.70[a]	7.60[a]	7.50[b]
Normal practice	7.68[b]	7.91	7.83	7.90	7.81[ab]	7.66[ab]	7.40[c]	7.50[b]	7.40[c]
Significance	*	ns	ns	ns	*	*	**	**	**

Tukey's significance: ns ($P \geq 0.05$); * ($P < 0.05$); ** ($P < 0.01$) for each colum followed with the same letter (a, b or c) do not differ at 5% significance level.

Table 3. Alkalinity (mg/l) in shrimp pond by farmer groups at the sampling dates in Hoa Tu 1 commune, My Xuyen district

Group	Mar.30	Apr.15	Apr.30	May 15	May 30	Jun.15	Jun.30	Jul.15	Jul.30
Pilot group	95.00[b]	83.20[b]	85.60[b]	83.60[b]	87.20[a]	88.60[a]	86.60[a]	80.60[b]	70.00[b]
Control group	116.75[a]	102.37[a]	95.75[a]	97.37[a]	92.75[a]	88.62[a]	87.87[a]	85.37[a]	80.87[a]
Normal practice	81.50[b]	80.50[b]	75.00[c]	72.00[c]	71.66[b]	71.50[b]	71.33[b]	70.50[c]	68.50[b]
Significance	**	**	**	**	**	**	**	**	**

Tukey's significance: ns ($P \geq 0.05$); * ($P < 0.05$); ** ($P < 0.01$) for each colum followed with the same letter (a, b or c) do not differ at 5% significance level.

and 4). Farmers used their filter ponds mainly in the 1st and 2nd month after stocking, and afterwards farmers exchanged water less frequently to decrease risk of disease transfer to other ponds. This modified practice caused higher nutrient and suspended matter concentrations in shrimp pond than that in irrigation canals (Lucia *et al*., 2012). This result suggested that filter ponds were effective for water treatment for shrimp pond. Shrimp farms did not exchange any water during the culture period, which favourable for limiting the spread of disease (Hoa *et al*., 2003; 2014).

Yields and economic return

The yield of tiger shrimp in the trials was low and did not differ between the groups (Table 5). Tiger shrimp yield ranged between 0.29 to 0.56 tons/ha. The latter is equivalent to the tiger shrimp yield of the regional survey (Tran Thanh Be *et al*., 2003) and it is also consistent with the experiment of Truong *et al*. (2003). However, the tiger shrimp farming cycle of the pilot group was shorter than both the control and normal farmer group (96 days versus 134 days, respectively). This faster growth might be due to the lower stocking density (Minh, 2018). This result suggests that the tiger shrimp stocked in high density will face with associated diseases shrimp (Tran Thanh Be *et al*., 2003). The shorter time period of the white-leg shrimp farming cycle allowed farmers to add one crop into the filter pond, which yielded between 2.0 to 2.6 tons/ha to augment the family income. Moreover, the Nile tilapia stocked in the filter pond for about 2 months yielded an additional 90 kg/ha.

Table 4. Salinity (‰) in shrimp pond by farmer groups at the sampling dates in Hoa Tu 1 commune, My Xuyen district

Group	Mar.30	Apr.15	Apr.30	May 15	May 30	Jun.15	Jun.30	Jul.15	Jul.30
Pilot group	6.96^{ab}	6.20	5.20	4.80	4.00	3.70^{a}	2.50^{b}	2.10^{b}	2.00
Control group	7.68^{a}	6.13	5.00	4.25	4.00	4.00^{a}	3.45^{a}	3.00^{a}	2.63
Normal practice	5.80^{b}	5.00	4.67	3.67	3.50	2.60^{b}	2.50^{b}	2.33^{b}	2.05
Significance	*	ns	ns	ns	ns	**	*	*	ns

Tukey's significance: ns ($P \geq 0.05$); * ($P < 0.05$); ** ($P < 0.01$) for each colum followed with the same letter (a, b or c) do not differ at 5% significance level.

Table 5. Yield components of shrimp by farmer groups in Hoa Tu 1 commune, My Xuyen district

Items	Pilot group	Control group	Normal practice	Significance
Tiger shrimp				
- Stocking density (PL/m^2)	4.1 ± 0.1^{b}	7.8 ± 0.9^{a}	7.1 ± 0.9^{a}	*
- Crop cycle (days)	96 ± 4.0^{b}	140 ± 6^{a}	134 ± 5^{a}	**
- Growth rate (g/day)	0.19 ± 0.01^{a}	0.14 ± 0.03^{a}	0.14 ± 0.02^{a}	ns
- Yields (ton/ha)	0.29 ± 0.03^{a}	0.56 ± 0.10^{a}	0.41 ± 0.06^{a}	ns
White-leg shrimp				
Stocking density (PL/m^2)	32.2 ± 9.2^{a}	30.6 ± 5.8^{a}		ns
Crop cycle (days)	62 ± 5^{a}	55.3 ± 4.7^{b}		*
Growth rate (g/day)	0.18 ± 0.01^{a}	0.17 ± 0.01^{a}		ns
Yields (ton/ha)	2.09 ± 0.48^{a}	2.63 ± 0.70^{a}		ns

Tukey's significance: ns ($P \geq 0.05$); * ($P < 0.05$); ** ($P < 0.01$) for each colum followed with the same letter (a, b or c) do not differ at 5% significance level.

In terms of economic return (Figure 3), the pilot and control groups earned a higher gross margin from shrimp farming than normal farmer group (from 882 to 1,295 compared with 423 USD/ha). The value of the tilapia harvested from the filter pond was 39 USD/ha. Farming white-leg shrimp, brought the pilot farmer and control farmer group a gross margin of 6,130 and 7,821 USD/ha, respectively (Figure 4). From these results it can be concluded that stocking Nile tilapia and white-leg shrimp in the filter pond increased household's income.

Rice farming

Economic return

Rice yield ranged from 6.2 to 6.9 tons/ha and was not significantly different among the treatment groups. The normal practice of rice farming reached a gross margin of 1,250 USD/ha, that was higher than the pilot farmer and control farmer groups: 854 and 1,051USD/ha, respectively. Compared to the normal practice, rice farming combined with the filter pond required more labour for transplanting rice, needed because of the high-water levels on the field, which increased the input costs and reduced profitability (Figure 5).

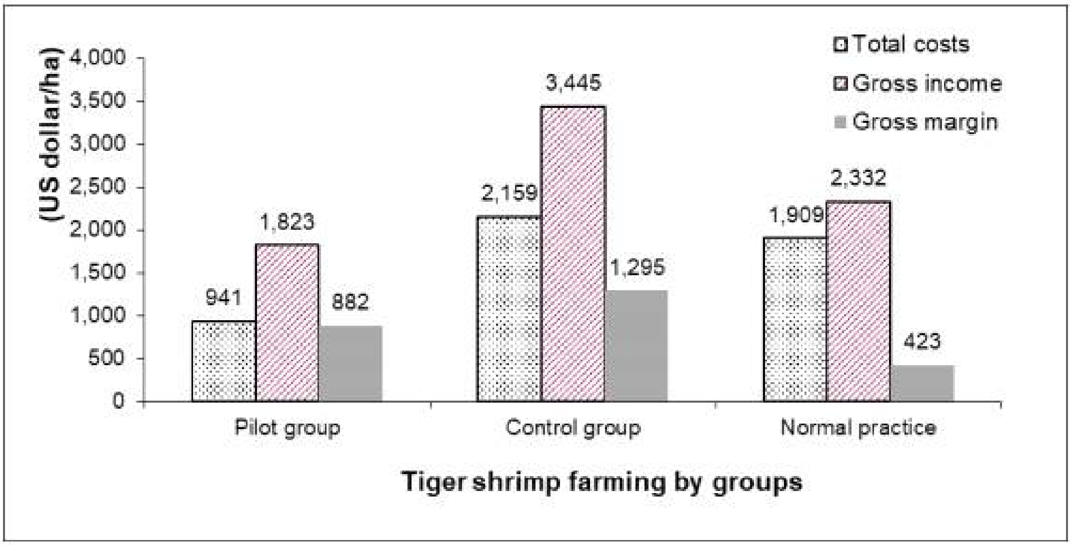

Figure 3. Economic return of tiger shrimp farming in Hoa Tu 1 commune, My Xuyen district.

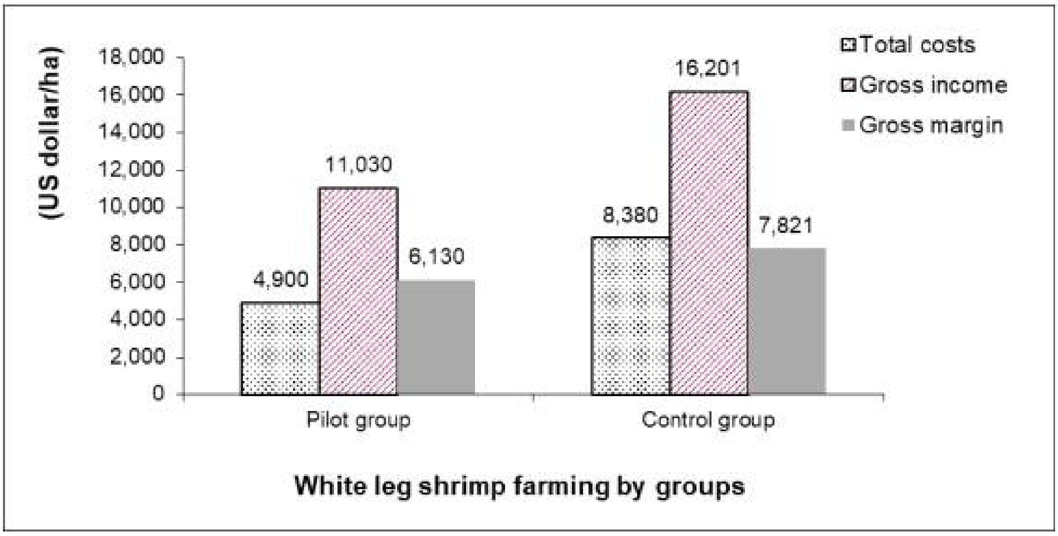

Figure 4. Economic return of white-leg shrimp farming in Hoa Tu 1 commune, My Xuyen district.

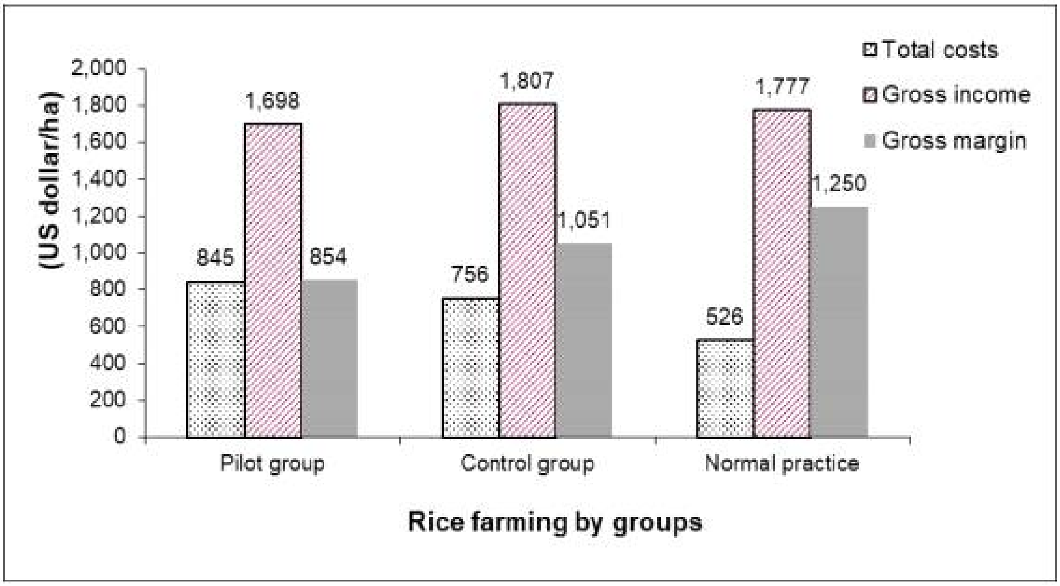

Figure 5. Economic return of rice farming in Hoa Tu 1 commune, My Xuyen district.

Rice field conditions

The pH of the soil in the rice field was around 6.9 and was similar in the two top soil players (Table 6). However, electrical conductivity (EC) of the soil was different, at the soil layer 0-20 cm was 7.8 S/m and at 20-30 cm it was 9.6 S/m. This result suggested that the water quality in the rice fields was not saline, but the high EC related to salinity was maintained at high levels in the soil. Therefore, need to pay attention to the saline wash in the rice fields before rice sowing to limit young rice died and adverse weather conditions such as drought or prolonged rain.

Table 6. pH and EC of soil in rice field in Hoa Tu 1 commune, My Xuyen district

Items	Soil layer (0 - 20 cm)	Soil layer (20 - 30 cm)
- pH	6.92 ± 0.34	6.95 ± 0.10
- EC (S/m)	7.82 ± 0.86	9.64 ± 1.03

This experimental result showed that the pH, alkalinity and salinity in the rice fields are in the suitable range for rice development. The pH value of the water in the rice fields and irrigation canals did not much fluctuate over the sampling period. The pH value on the rice field ranged from 6.9 to 7.6 and in irrigation canals ranged from 6.6 to 7.6 over sampling times and during the period of rice farming. Alkalinity (mg/l as $CaCO_3$) in water of rice field did not much change over the sampling period and remained within the suitable range for rice farming. Water alkalinity in rice field ranged from 82 to 128 mg/l, and water alkalinity in canals varied between 75 and 90 mg/l. The salinity of water ranged from 0.1 to 1.0 ppt across the sampling dates. The water salinity in the study area measured below 1.0 ppt is tolerable level for both shrimp and rice growth (Gaona *et al*., 2013).

Upland-crop practices on field dikes

Characterization of soil

The fields on the dikes were affected by acidity with pH = 5 and salinity (0.9 to 1.3 ppt). However, soil pH improved, and salinity decreased during the cropping (Table 7). The soil analysis also showed that the farm land was rich in nitrogen and organic matter, but poor in phosphate and potassium. The chemical properties of the soil were at the limits for the cultivation of upland-crops. Therefore, adding of lime ($CaCO_3$) before planting to improve soil pH is recommended.

Upland-crop farming

The financial analysis of the upland-crops on the dikes showed that vegetables have the highest return, followed by food crops (sorghum) and Taro, a root crop (Table 8). The gross margin of vegetables was about 4,304 USD/ha, while sorghum was less than half (1,733 USD/ha) and taro earned 679 USD/ha. The potential gross margin of cropping grass for cows was highest (2,737 USD/ha/year). Profit from cultivating upland-crops will be higher if farmers can do two crops/year or combine upland-crops in the rainy season with sorghum for feeding livestock in the dry season. Growing upland-crops and grass for cows consumed had the highest return, however that required more labour intensive than sorghum and taro (328 compared with 260 days/ha, respectively). Sorghum farming is a promising crop for feeding poultry. In particular if in the future climate change results in prolonged droughts and water shortages, the sorghum can adapt well.

Table 7. Characterization of soil on the field dikes of rice-shrimp farming system in Hoa Tu 1 commune, My Xuyen district

Items	Day before sowing	60 days after sowing	Day of harvesting
- pH	4.74 ± 0.40	4.83 ± 0.48	5.17 ± 0.55
- Salinity (ppt)	1.26 ± 0.08	1.09 ± 0.20	0.93 ± 0.11
- Nitrogen (N %)	0.63 ± 0.09		
- Phosphorus (P %)	0.06 ± 0.01		
- Potassium (K %)	1.89 ± 0.10		
- Organic material (OM %)	4.20 ± 0.70		

Table 8. Economic return of upland-crop cultivation in the field dikes (Unite: US dollar/ha) in Hoa Tu 1 commune, My Xuyen district

Items	Total cost	Gross income	Gross margin	Labour (days)
1) Taro	1,495	2,174	679	250
2) Sorghum	2,213	3,947	1,733	260
3) Vegetables	2,804	7,109	4,304	328
4) Feed grass + cows	3,250	5,987	2,737	365

Financial return of integrated farming systems

The financial return of one hectare of farm land for different integrated farming system was different (Figure 6). Rotation between tiger shrimp and rice cultivation combined with white-leg shrimp and upland-crops or cropping grass for cows are more profitable than the normal or traditional practice (tiger shrimp + rice). The most profitable model among the tiger shrimp + rice + white-leg shrimp + vegetables, had a gross margin of 2,812 USD/ha/year. The normal or traditional practice of rice-shrimp had a gross margin of 854 USD/ha/year. However, the integrated farming system was more labour intensive than the rice-shrimp system (Table 8), which is a limiting factor for farmers' implementation. The integrated farming system requires a filter ponds, suitable management skills and family labour resources. Having few family labour resources would be a constraint for diversification of household activities. In terms of adaptation to climate change such as low rainfall, changing weather, water pollution and saltwater extends diversification of farm activities and implementation of an integrated farming system provided farmers a more stable income than rice-shrimp farming.

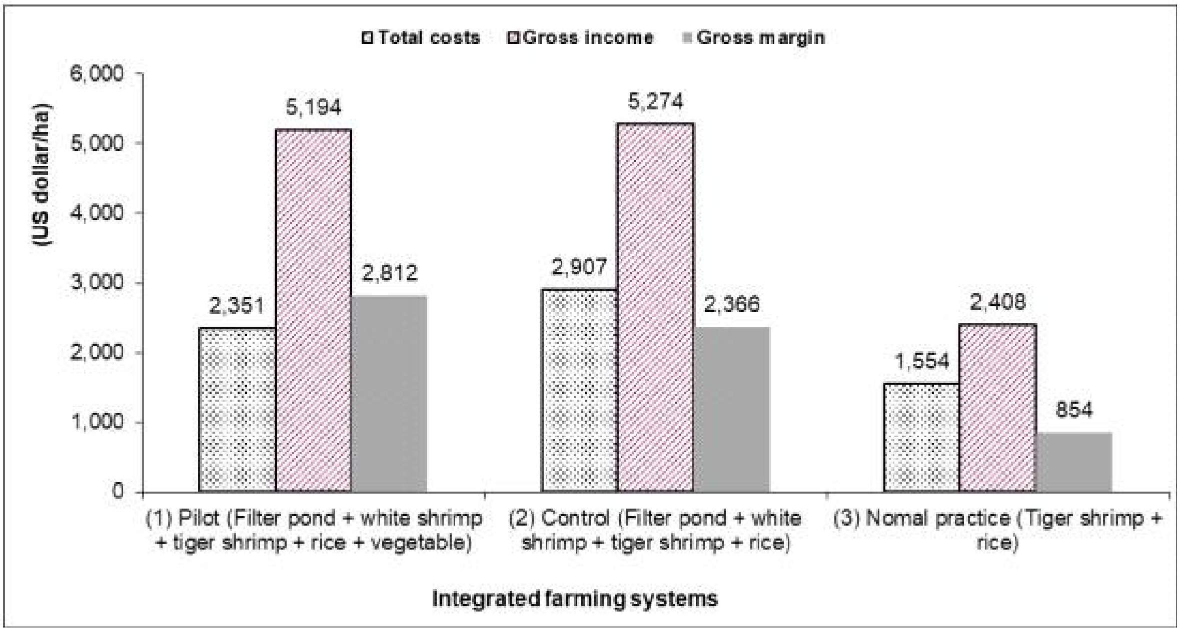

Figure 6. Economic return of integrated farming systems in Hoa Tu 1 commune, My Xuyen district.

CONCLUSIONS

Filter ponds stocked with tilapia can improve water quality (pH level, alkalinity and salinity in shrimp pond at pilot and control farms were higher than farmers in normal practices) and contributed to reducing the shrimp farming cycle (pilot group was shorter than both the control and normal farmer group; 96 versus 134 days). Stocking white-leg shrimp in the filter pond had a high financial return and growing upland-crops on pond dikes had a high financial return, especially vegetables. Cultivating upland-crops will provide a higher income if farmers do two crops/year or combine vegetables with sorghum to produce feed for livestock. However, farming upland-crops required more labour; having few family labour resources will be the limiting factor for producing crops on the dikes.

Farmers using filter ponds to support rice-shrimp farming system and combined upland-crops or planting feed grass for cows had a higher financial return than normal farming system. Diversification of household activities through integrated farming will enable farmer's adaptation to impact of climate change such as extreme weather events, less rain and saltwater intrusion.

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