Eco. Env. & Cons. 26 (February Suppl. Issue) : 2020; pp. (S44-S52)
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ISSN 0971–765X

Economic analysis of different aquaculture systems in coastal buffer zones of protected areas: A case study in Xuan Thuy National Park, Vietnam

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(Received 24 October, 2019; accepted 25 November, 2019)

ABSTRACT

The paper aims to achieve two goals. First, ithighlightsthe differencesof aquaculture systems in the buffer zones of Xuan Thuy national park, Vietnam. Second, it serves as an assessment of the economic performanceand factors that influence net farm income of the systems. A formal survey was used to collect relevant data from 138 farmersin intensive shrimp (ISH) and integrated aquaculture-mangrove (IAM) farming systems. Results demonstrated that ISH produced a total 1,017 million Vietnam Dong (mil.VND) value of output per hectare annually which was more than 32.99 mil. VND from IAM. ISH carried a much higher cost of production (695.39 million VND/ha/year) than IAM (13.29 million VND), and ISH obtained relative higher net farm income (321.17 million VND) than IAM (19.70 million VND). Ordinal least square (OLS) regression was used to assess relationships between social-economic-environmentalfactors on the net farm income. Maintaining more forestry coverage and reduce the negative effects of polluted water from surrounding rivers are important to achieve greater income of IAM production. Meanwhile, stimulating formal and informal knowledge together with increasing farmers' power in bargaining prices simultaneously reducingnegative effects of polluted water, disease occurrence and production costscan help to improve the net farm income of ISH production. The expanded analysis is necessary to render value contributions to ensure farmers receive a higher level of economic returns while conserving the natural ecosystem for the protected areas.

Key words : *Economics, Aquaculture system, Xuan Thuy national park, Buffer zones, Vietnam*

Introduction

Vietnam haslong coastlines of 3,260 km which are preferable for mariculture development. In 2016, the total production of fisheries of Vietnam was 2.44 million tons in which 1.15 million tons of catfish followed by 0.65 million tons of brackish-water shrimp (Southeast Asian Fisheries Development Center, 2018). With its appropriate potentiality and natural conditions, Vietnam was ranked at 4th emerging shrimp producer country in the world (ordered as India, China, Ecuador, and Vietnam) (Vigo, 2018). Culturing of shrimp in Vietnam are classified into four production systems based on level of technology applied, stocking density and yield including extensive, improved-extensive, semi-intensive, intensive and integrated (Gowing *et al.*, 2006; Can, 2011). Intensive system relies on high stocking density at 66 seed/m^2 with heavy feeding rate (FCR at 1.31), application of aeration, yield gains at an average of 6,974 kg/ha/year (Engle *et al.*, 2017). The trend toward intensification production is likely driven by economies of scale that are recognized by widely culturists. Strong market demand creates incentives for farmers to aim at a quick return on investments. Extensive is traditional methods based mainly on natural recruiting post-larvae from wild sources and the ecosystem; pond size is typically above 10 ha; trap and hold wild shrimp are at a density of 1-3 seeds/m^2; yield typically gains less than 200 kg/ha/year. Semi-intensive involves some stocking of shrimp larvae from a hatchery; the productivity is enhanced by some use of feeds and fertilizers; ponds covers 2-10 ha; water exchange is provided mainly by the tide; prawns are stocked at the rate of 3-10 seeds/m^2; yield typically gains at 1,000 - 2,500 kg/ha/year. Intensive system relies on high stocking density at >10 seed/m^2 in small pond size (1-2 ha) with heavy feeding rate; aeration are required in ponds; yield gained at > 5,000-7,500 kg/ha/year (Gowing *et al.*, 2006). After the period of 2000-2006, semi-intensive and intensive farming systems were quickly expanded from 0.36 million ha to 0.7 million ha in almost coastal provinces of Vietnam (Can, 2011). In the integrated system, shrimp larvae and other marine life are managed in mangrove forest along coastlines. In this system, shrimp yield can reach 200-300 kg/ha/year (Can, 2011). Shrimp production in Vietnam contributes significantly to food baskets, but a high level of risk and indebtedness are concerned (Gowing *et al.*, 2006). Financial risks including cost and loss increase incorporate with intensive level of production. Although average returns may be higher, they tend to depend on large fluctuation of market prices and environmental factors. In addition, some diseases directly spread cause financial loss for farmers. According to Little (2011), shrimp sector of Vietnam has suffered from high production costs and low effectiveness. Different types of culture systems have different economic results and obstacles. Farmers must understand clearly about the economic viability of the production and address constraints for sustainable incomes.

Xuan Thuy National Park (XTNP), UNESCO biosphere reserve and Ramsar site, is the largest coastal wetland ecosystem in Northern Vietnam. The park comprises the core zone and buffer zone. The buffer zone is established with aims at developing the social-economic status of local communities and minimizing environmental impacts on the core zone. Buffer zones include five peripheral communes (Giao Thien, Giao An, Giao Lac, Giao Xuan, and Giao Hai) with a total area of 8,000 ha and have total of 44,287 peoples in 14,076 households (Buffer communes, 2018). Aquaculture is considered as the main engine of growth for rural inhabitants. It sustains 36% of annual income (Vietnam Administration of Forestry, 2017) for locals. Shrimp farming has been expanded rapidly from 121 hectares in 1986 to 938 hectares in 1992, and 1,706 hectares in 2001 (Beland *et al.*, 2006). This sector is economically important as the primary species reared in this area. However, the absence of responsible practices and contradiction exists between water users are challenges for aquaculture sector. There were 100% of intensive shrimp (ISH) and 33% of integrated aquaculture-mangrove (IAM) farmers complained their intake water had been impacted by waste disposal from surrounding ISH ponds because manyfarm owners do not allow the standard treatment process. Moreover, many farmers also concerned about pesticide contaminants from nearby paddy fields through agricultural control gates in the area. Besides the degradation of the natural environment, other social-economic factors contribute to the fluctuation of aquaculture performance recently such as education and power of price bargaining, etc. From an economic context, we have found many obstacles lie on roads to the improvement of sustainable income of aquaculture in this area. The lack of information on the economics might lead to the mismatch between short-term profits and long-term development for this conservation site. The economic analysis can provide a systematic evaluation of aquaculture management and help farmers to manage their production more sustainably.

This research aims to (1) analyze different characteristics of IAM and ISH aquaculture systems in coastal zone of XTNP regarding diverse management practices, farm outputs, economic performance, and (2) assess social-economic-environmental factors that had significant impacts on net farm income of the two systems. It is hoped that to render propose value recommendations for ensuring two groups of farmers receive a higher level of profits through the application of environmental friendly farming practices and improving other social-economic factors.

Research Methodology

Description of the Study Site

Xuan Thuy National Park (XTNP), a Ramsar site with international importance, locates in Giao Thuy district, Nam Dinh province. The park situates on the Ba Lat estuary of the Red River Delta. The average salinity is from 11‰ - 30‰. The variation of salinity depends on the months and locations. The area has under the tidal with the highest amplitude is 3.3 meters and the lowest height is 0.25 meters. The protected area is a garden for about 40,000 migratory birds yearly. For Vietnam, it brings great potential for natural resources providing food, creating environment and nursery for aquatic habitats.

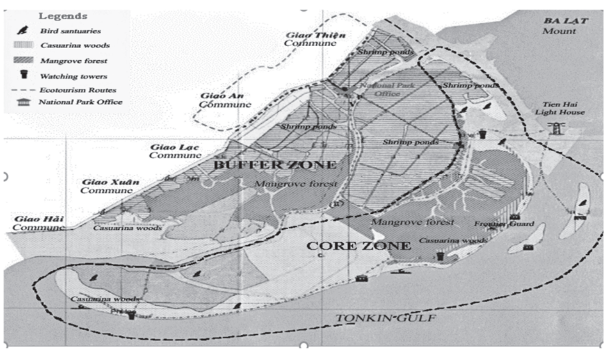

Fig. 1. Map of Xuan Thuy national park

The core zone of XTNP covers 7,100 ha including two areas of terrestrial (3,100 ha) and wetland (4,000 ha). The buffer zone covers 8,000 ha including Ngan islet (the boundary runs from the lagoon dike to the Vop river canal), Bai Trong and five peripheral communes. Overall, XTNP has seven ecosystem typologies, including tidal wetland with mangroves, tidal wetland without mangroves, aquaculture-mangrove farming, rice farming, sandy coastal line, tidal rivers, and estuary.

The mangrove forest in the core zone is an important ecosystem. There are two types of mangroves consisting of natural and planted. The natural mangrove forest has higher biodiversity values (Phan *et al.,* 2007). It ranges between eight to ten meters in height. They are three canopies andseven species of mangrove in this area (Hoang *et al.,* 2013). The planted mangroves include two species which is of lower stature at five meters. Mangroves also play crucial functions in the park as providing living conditions for habitats and other wetland species, especially for migratory birds.

Buffer zones of XTNP lies outside the boundaries of XTNP core zone and include 5 communes with a total of 44,287 peoples (Buffer communes, 2018). The zone is established with aims at developing the livelihood of surrounding residents while minimizing environmental impacts on the core zone. In this study, we choose farms located in Ngan islet for data collection. Ngan islet lies between Tra and Vop rivers, the largest islet of the reserve site. The islet covers approximate 2,000 hectares, in which 1,524 hectares are mangrove forest lie in both core zone and buffer zone. There are 57.74% of total mangrove forest lie in the buffer zone and they have been used for integrated aquaculture farming. There are two main aquaculture farming systems in Ngan islet, including integrated mangrove – aquaculture and intensive shrimp.

Data Collection and Analysis

Many farmers build farms and raise aquaculture in a group since it is hard to choose farm owners for interviews based on the list of farmers provided by communal administration. We decided to choose sample size based on farm locations initially, then we found representatives of farms for face – to – face interviews. After reviewing and assessing farms under five communal administration in the buffer zone, farms in Ngan islet which administratively under Giao Thien communal management meets set criteria and selected for data collection, becausethe farms situated near the core zone and Ba Lat estuary and it is the unique buffer area which has 150 ha of intensive shrimp culture. Fieldwork was carried out in XTNP area from 2017 to 2018 by means of standard and semi-structured questionnaires. Standard questionnaires were used to collect data from 84 integrated aquaculture – mangrove, 54 intensive shrimp farmers. Household survey aimed to capture detail information on production practices and receipt such as total production, profits, etc.

Different types of farming models have different returns depend on diverse factors. Ordinal least square (OLS) regression was applied in this analysis to estimate relationships between factors and net farm income.

Econometric models of integrated aquaculture-mangrove system (IAM)

$$Y_{IAM} = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5 + \varepsilon$$

where Y_{IAM} = net farm income (per hectare/year) of IAM; a_0 = constant, autonomous level of net farm income (a_1- a_5= regression co-efficient); ε: error term; X_1= Training attention (times/crop); X_2= Stocking density (PL/m^2); X_3= Effected by polluted intake water (Dummy: yes/no); X_4= Mangrove coverage in farm (%); X_5 = Production cost (mil.VND/ha/crop);

Econometric model of intensive shrimp farming system (ISH)

$$Y_{ISH} = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5 + a_6X_6 + a_7X_7 + a_8X_8 + \varepsilon$$

where Y_{ISH} = net farm income (per hectare/year) of ISH; a_0 = constant, autonomous level of net farm income (a_1- a_5= regression co-efficient); ε: error term; X_1= Education (year); X_2= Advisory service received from input dealers (Dummy: yes/no); X_3= Effected by polluted intake water from surrounding ponds (Dummy: yes/no); X_4= Disease occurrence (Dummy: yes/no); X_5= Production cost (mil.VND/ha/crop); X_6= Effected by pesticide contaminants from adjacent rice farms (Dummy: yes/no); X_7= Price squeeze (Dummy: yes/no); X_8= Farm size (ha).

Results

Aquaculture Systems in the Buffer Zones of Xuan Thuy National Park

IAM culturists apply poly-culture with various species that are cultured include black tiger shrimp *(penaeusmonodon)*, greasybock shrimps (*metapenaeusensis*), crabs, fish, and seaweed. Crop lasts from April to November yearly, the remaining time (from December to March) farmland is dried in 2 weeks then the sluice gate is opened for intake water with some natural wild habitat (milkfish, shrimps).The average size of one farm is 6.45 hectare but there is no standard design for IAM ponds. Present-day, the culture practices of IAM still heavily rely on the experience of individual farmers.A concrete gate is built to have an adequate amount of water. It has several grooves for harvest nets. Dikes around shrimp pond are constructed as boundaries to indicate pond size and shape. Mangroves are integral to natural ecosystems, protecting against tidal waves and storm surges, and providing vital fish nursery grounds. Mangroves cover about 24.28% of total farms which contribute to the provision of wild feedstock and organic waste for food of the marine. Farmers stockedshirmp at a density of 5.47 PL/ m². Shrimps' food is mainly ephemera, but some bivalves and miscellaneous fish are mixed with rice bran are used at the first 15-20 days of shrimps. None of fertilizers or chemicals are applied in rearing. Farmer harvest shrimps and crabs around July-August, then fish and seaweed are collected until November. Aquatic products are harvested by draining the pond at low tide through a bag net installed in the outlet sluice gate. Shrimps and fish then follow the water flows and then trapped in nets attached to this gate.

Month	Intensive shrimp (ISH)	Integrated aquaculture – mangrove (IAM)
Jan.	Fallow	Fallow
Feb.		
March	Pond preparation, releasing shrimp post-larvae, Feeding and water management	
April	Feeding and water management	Releasing shrimp post-larvae, crabs Feeding and water management
May	Feeding and water management	Feeding and water management
June	Feeding and water management, Harvesting	Feeding and water management
July	Fallow	Feeding and water management
Aug.	Pond preparation, Releasing shrimp post-larvae.	Harvesting shrimp, crabs
Sep.	Feeding and water management	Harvesting crabs, fish
Oct.	Feeding and water management	Harvesting crabs, fish
Nov.	Feeding and water management Harvesting	Harvesting seaweed
Dec.	Fallow	Fallow

Source: In-depth interview, 2017-2018.
Note: Season 1: Season 2:

Fig. 2. Farm activities of aquaculture farming in the buffer zone of XTNP

The People's Committee of Giao Thuy district issued the decision number 4803/QD-UBND in 2014 to change 150.37 hectare of rice-shrimp system in XTNP's buffer commune to intensive shrimp system. Culturists applymonoculture with two raising cycles per year. Farmers construct ponds near coastal rivers or IAM farms where ponds can be completely drained and dried before stocking. The first production cycle usually starts with pond preparation in March and harvest in June. The second cycle lasts from the end of July to November with longer growth duration. White legged prawns (*Penaeus vannamei*) are conducting witha stocking rate of fries of about 76 post-larvae/m^2. This system depends heavily on aeration to circulate water for oxygen for shrimps. Shrimp are simply harvested with large scoop nets when required for selling. Size of harvested shrimps is about 80heads/kg. After harvest of the second production crop, farmers clean ponds and leave them fallow in three months

Table 1. Technical characteristics of two aquaculture farming systems

Items	IAM	ISH
Production system	Black tiger shrimp – Crab (Co- products: wild-catch shrimp/fish, seaweed)	White legged shrimp–White legged shrimp–Fallow
Diversity of species	Polyculture	Monoculture
Farm size/farm owner (ha)	6.82	1.60
Mangrove coverage in farm (%)	24.28	0.00
Stocking density (PL/m^2)	5.47	76
Seed source	Hatchery and wild	Hatchery
No. of crop/year	1	2
Chemical used	None	Widely used
Survival rate of shrimp (%)	40-45	50-70
Feed used	Bivalves,miscellaneous fishes	Artificial
Water exchange	Tidal (7 times/month)	Pumping (3 times/week)
Aeration	None	Every hour
Employment (person/ha)	0.2	1
Disease occurrence	Moderate	Frequent
Causing pollution for adjacent water	Moderate	Much
Threatening to migratory birds	Moderate	Much

Source: Survey 2017-2018

from December to February.

In ISH, each rearing pond has an average depth of 1.2 meters and stores around 1,200 m^3 of water. Pond embankments are covered with nylon matting and the middle bottomis served as a collection of wastes and residues. Two control gates for water exchange are located in the corners. Two aeration device systems are available for water circulation for a pond which has an average size of 1000-1500 m^2. Farmers construct supply and drainage canals separatelyto pumpintake water from public rivers or nearby IAM farms then drain pond sludge to drainage canals or directly to common rivers. All of ISH producersstrictly follow standard water quality for shrimp such as pH, salinity, DO, NH_3, CO_2, etc. Nonetheless, this research concerns that major farmers no longermeasure effluent quality before draining it into adjacent water. There are only 33% of ISH farmers applied several basic techniques for water treatment after harvesting shrimps such as using lime or raising tilapias and other fish inside drainage canals. Brackish water quality and effluent standards are introduced by the Vietnamese Ministry of Agriculture and Rural Development but farm owner recognized the standards and permits as recommendations.

Cost and Returns

Costs of production and other economic indicators are presented in Table 2. The costs were classified into two groups including variable cost (family and hired labor, food, aquaculture post-larvae, electricity, antibiotics, supplement and vitamins, and other drugs) and fixed cost (depreciation of equipment and tools, land use fee and interest). Diverse equipment and tools are set up for ISH such as electrical systems, tanks, aerations, generators, and pumps, pipes, etc., while IAM needs only water control gates and watchtowers (tents) with expected usage in around 20-30 years. Modernization has led ISH farmers to use a diverse range of nonfarm-produced items including pelletized feed, supplement and vitamin, antibiotics and probiotics, etc. We also have found that 100% of ISH producers managed their marine habitats with supplement. Antibiotics were used to strengthen health and reduce mortality of shrimp frequently and cure diseases sometimes by 87.04% of farms. With increased stocking density, management becomes more difficultly and farmers may attempt to sterilize the pond environment with chlorine and diverse drugs. Nevertheless, IAM farmers do not involve pelleted feed, additive nutrients, and drugs. ISH required carried a much higher cost of production (695.39 million VND/ha/year) than IAM (13.29 million VND), but ISH obtained relative higher net farm income (321.17 million VND) as compared as IAM (19.70 million VND). In the following, we have analysis for explaining factors influencing net farm income of IAM and ISH.

Profitability and the value of goods produced (value of farm production) during a year are economic assessment of agriculture development (Anna Gaviglio, 2017). This measurement was also investigated by Jane Dillon *et al.* (2016) when the researcher calculated the farm productivity. IAM provided 69.89 kg black tiger shrimp products per ha per year which was less than those in Ca Mau coastal province, which gained 300 – 400 kg per ha with average stocking density from 1- 6 post-larvae/m^2 (Seafood Trade Intelligence Portal, 2018). Although IAM produces a smaller number of reared shrimps than ISH but it provided diverse foodstuffs in several months for farm households. Our results indicate that both ISH and IAM farmers preferred IAM products. ISH produced about 7,489 ton/ha in two seasons, but the this productivity was lower than average number of four provinces of Vietnam, which gained 11,500 kg/ha/crop in 92 day production crop with stocking density of 109 PL/m^2 (Thakur *et al.,* 2018).

Determinants of Net Farm Income of Aquaculture Systems

Economic performance of shrimp aquaculture depends on various factors regardingsocial-economic-environment and farm management skills. Table 3 shows the results of multiple regression estimation on the factors influencing net farm income of IAM. The coefficient of multiple determination (adjusted R^2) of 0.336 implies that 33.6% of the variations in net farm income are explained by the joint action of

Table 2. Economic performance of aquaculture systems

Economic indicators	Unit	IAM	ISH
1. Output quantities	kg/ha/year		
1.1.Target product		69.89	7,489
1.2.Co-products			
Crab		16.35	-
Wild-catch shrimp		49.07	-
Wild-catch fish		9.77	-
Natural bivalve		17.78	-
Natural seaweed		642.31	-
2. Total revenue	Million VND*/ha/year	**32.99**	**1,017.00**
3. Total cost	Million VND/ha/year	**13.29**	**695.39**
3.1. Variable cost		10.70	643.66
Labor		4.48	73.98
PL- shrimp		2.79	96.89
PL- Crabs		2.48	0.00
Feeds		0.41	243.11
Miscellaneous		0.34	0.00
Lime		0.20	11.20
Sand		0.00	17.53
Chlorine		0.00	10.85
Bacteria/virus drugs		0.00	6.46
Antibiotics		0.00	42.33
Pro-biotic		0.00	39.78
Supplement		0.00	37.24
Electricity		0.00	57.32
Oil		0.00	6.97
3.2. Fixed cost		2.59	51.73
Landannual rental		0.35	1.5
Interest		0.40	16.93
Repairs		1.21	0.00
Depreciation		0.63	33.30
4. Net farm income	Million VND/ha/year	**19.70**	**321.17**

(*) 1 USD = 22,385,000 VND on 14th July 2019. Source: Survey 2017- 2018.

the independent variables. On one side, the estimation shows that mangrove coverage (0.451), production cost (0.984) have positive and significant linkages with net farm income. This means that the net farm income will increase if these factors are increased above their present use. On the other side, polluted effluents from surrounding ponds (17.787) havean inverse influence on net net farm income. This suggests that if farms are affected by external pollution, the farm income will decrease significantly. The formula of the OLS regression was as follow:

Net Farm Income (IAM) = 9.072 + 0.451* **Mangrove** + 0.984* **Production Cost –**

17.787* **Polluted Effluent**

Table 4 shows the results of OLS estimation on the factors influencing the white legged shrimp net farm income of ISH system. The estimation confirms that advisory received from input suppliers (57.336), educational level of farm owners (36.772) have positive relationships with net farm income. Meanwhile, polluted effluents from surrounding ponds (120.466), pesticide effect from adjacent rice fields (90.505), disease occurrence (80.654), price squeeze (63.731) and production cost (0.303) inversely influence on the net farm income. The formula of the OLS regression was as follow:

Net Farm Income (ISH) = 126.27 + 36.772* **Education** – 90.505* **Pesticide residue –**

0.303* **Production Cost** + 57.336* **Advisory service** – 80.654* **Disease occurrence** – 120.446***Effluent –**

63.731***Price squeeze**

Conclusions and Implications

The study concludes by emphasizing different characteristics of IAM and ISH aquaculture systems in

Table 3. The influence of social-economic-environmental factors on net farm income of IAM

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
	B	Std. Error	Beta			VIF
Constant	9.072	9.523		0.953	0.344	
Mangrove	0.451	0.165	0.302	2.728	0.008	1.458
Production cost	0.984	0.390	0.273	2.520	0.014	1.395
Effluent effect	-17.787	5.712	-0.326	-3.114	0.003	1.304
Stocking density	1.235	0.943	0.127	1.309	0.195	1.120
Training	2.166	3.009	0.083	0.720	0.474	1.593
R Square = 0.368; Adjusted R Square = 0.336;						
F(6,73) = 7.656 (p< 0.00001); Durbin-Watson = 1.859						

Source: Compiles from data survey, 2018. Note: the estimated results were calculated for surveyed farm in two growing seasons.

Table 4. The influence of social-economic-environmental factors on net farm income of ISH

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
	B	Std. Error	Beta			VIF
Constant	126.274	80.459		1.569	0.120	
Education (years)	36.772	6.673	0.428	5.511	0.000	1.304
Pesticide residue	-90.505	28.376	-0.247	-3.189	0.002	1.300
Production cost	-0.303	0.106	-0.252	-2.847	0.005	1.697
Advisory received	57.336	25.402	0.174	2.257	0.026	1.292
Disease occurrence	-80.654	25.596	-0.240	-3.151	0.002	1.253
Effluent effect	-120.466	26.640	-0.346	-4.522	0.000	1.270
Farm size	-13.013	14.187	-0.067	-.917	0.361	1.158
Price squeeze	-63.731	23.986	-0.187	-2.657	0.009	1.069
R Square = 0.743; Adjusted R Square = 0.506;						
F(10,97) = 11.94 (P < 0.001); Durbin-Watson = 1.46						

Source: Compiles from data survey, 2018.

the coastal zone of XTNP according to diverse management practices, farm outputs, production costs, and economic performance. ISH produces a much greater volume of commercial white legged shrimps than back tiger shrimps and other aquatic species of IAM. Although IAM obtained less profitability than ISH, the integrated systemis recognized as a higher potential to provide steady and diverse foods for household consumption. We also have found that the growth of marine habitats in ISH rely more on artificial purchased inputs such as pelletized feed, antibiotics, veterinary medicine, etc., whilst IAM system depends mainly on supports of nature without the involvement of these additive feeds.

The regression analysis reveals different levels ofinternal and external factors on net farm income. Both systems depend on supports from the coastal environment. According to Kautsky *et al.* (2000), natural environment supplies feed, seed, clean water, and waste assimilation for aquaculture. Discharge of untreated effluents of ISH into a common water body is one of improper management practices, which may contaminate water quality and spread disease to adjacent farms. Our estimation results reveal negative between ISH net farm income and effluents from water sources and pesticide residue from rice areas. The risk of disease outbreak has another substantial negative impact on the economic performance of farms. Likewise, disease occurrence, diverse other factors from social-economic dimensions including the cost of production management and price squeeze can largely challenge economic viability and affect the profitability of the shrimp system. The best management practices (BMPs) for coastal aquaculture presented by Boyd (2003) should be considered as a practical mean for preventing negative impacts of the natural environment and ensuring economic efficiency in this area. Effluent disposal also can be mitigated through adoption of (1) polyculture or diversification of cultured species including fish, mollusks, mangrove, halophytes, and artemia; (2) reduction of water or zero exchange rate; (3) use of oxidation-sedimentation ponds; (4) improving the delivering and composition of the feed (Primavera, 1991; Chua, 1992; Hopkins *et al.,* 1995). Disease outbreak can be addressed by ensuring good water quality and lower stocking densities; environment control; high health seed and disease control (good feed with uses of probiotics) (Primavera *et al.,* 1993; Hopkins *et al.,* 1995; Primavera, 1998). According to Hossain *et al.,* (2013), treat and re-circulate pond sludge are technical measures for the reduction of pollution by sewage. More importantly, water quality restriction regulations for shrimp aquaculture in Decree No.22/2014/TT-BNNPTNT approved by MARD (Ministry of Agriculture and Rural Development, 2014) should be assured for enforcement in the site.

More mangroves trees and higher investment are considered as other measurements for better net farm income of black tiger shrimps and co-products in IAM. Maintaining optimal tree cover in these farms can help to overcome mangrove degradation in XTNP area notified by previous researchers (Beland *et al.,* 2006). Mangroves also provide more nests and food for migratory birds in the coastal protected area. Furthermore, mangroves can be used to treat shrimp pond effluents with solids, organic matter, and nutrients (Rajendran and Kathiresan, 1996). On the other hand, an increased level of purchased input use might create more dependency of a farming system on external inputs (Rao *et al.*, 2017). This requires a higher capacity for cost management from IAM farm owners.

The further estimation results demonstrate the positive relationships between net farm income and receipt of advisory service and education level of ISH farm managers. Enhancing formal and informal knowledge and problem-solving skills for farmers can stimulate economic returns of white legged shrimps. The government needs to subsidize or invest more in researches, training and extension in this zone. Besides, in order to help smallholding farmers raise power in bargaining prices, some resolutions are proposed including (1) forming farmer groups of selling; (2) promoting grants or cheap credits for farm owners who follow environmentally-friendly practices or designs; (3) introducing environmental quality labeling programs to develop high-value shrimps with traceability.

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