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Efficiency of Different Integrated Agriculture Aquaculture Systems in the Red River Delta of Vietnam

Nguyen Van Huong[1,2*], **Tran Huu Cuong**[1], **Tran Thi Nang Thu**[3] **and Philippe Lebailly**[2]

[1]*Faculty of Accounting and Business Management, Vietnam National University of Agriculture, Hanoi, Vietnam*

[2]*Gembloux Agro BioTech, University of Liege, Belgium*

[3]*Faculty of Fisheries, Vietnam National University of Agriculture, Hanoi, Vietnam*

***Corresponding author:** Nguyen Van Huong, Gembloux Agro BioTech, University of Liege, Belgium, Tel: +0032 488578 061; E-mail: nghuonghd76@gmail.com

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Abstract

Freshwater aquaculture production systems are closely related to Integrated Agriculture Aquaculture systems (IAA). Four systems were identified from freshwater aquaculture farming in the Red River Delta of Vietnam. There was prevalently VAC system existence both inside and outside the residential area. The system was defined as farming diversifications and nutrient linkages among V (orchard), A (pond) and C (animal) components relying on the on-farm resources and off-farm integrations and linkages with other human activities. The development of the freshwater aquaculture systems was very diverse and dynamic.

The paper presented the economic efficiency and effectiveness on four freshwater fish production systems. Clear evidence was found to provide evidence that the traditional VAC system was sustainable food supply model for the developing countries. Farms operated the VAC systems could easily diversify their farming activities, foods, foodstuffs, redundant employment, and income. Especially, income diversification was a practical strategy for rural farms to reduce the vulnerability on their agricultural practices both on production and market risks. The advantages were likely to ensure that VAC systems would still be more and more important role in northern Vietnam for food security and rural development under the context of agricultural land loss by transforming progressively into urbanisation and industrialisation.

Keywords Freshwater aquaculture; Production; Systems; VAC; Food; Rural development

Introduction

Freshwater aquaculture was an important component of the supply of animal-based protein, amino acids, fatty acids, minerals and vitamins in the diets of predominantly poor populations in the developing countries of South East Asia [1-4]. The aquaculture production systems were predicted to become more intensive and uniform. Its output will, on the one hand, satisfy the growing demand of mass markets for safe animal-source products [5].

Freshwater aquaculture was acknowledged to contribute to a sustainable method to assure food security, to alleviate poverty thank to its diversification of products [3,4,6]. On the other hand, the ecological cooperation aquaculture (Fish-Vegetable Mutualism) model would be an effective way to solve the problem caused by traditional freshwater aquaculture to reduce the generation and discharge coefficient of fish pond [7].

Particularly, it had been inherent with the poverty reduction strategy orientation/plans or had become a key part of macro-economic growth, at some extent, in many countries. The renewed approach in which various types of aquaculture could contribute to poverty alleviation at household, community and national levels was critical [8]. Freshwater fish contributes to 12.4% of the 29 gram capita-1 day-1 animal-based protein supply [9], of which 37% was supplied by the cyprinid and cichlid species and mainly produced through aquaculture [10] in Vietnam.

Having diversely and densely populations, there was prevalent existence of freshwater aquaculture production systems in the Red River Delta-northern Vietnam and in most other populated regions in Asia [6,11,12]. The principal component of Integrated Agriculture Aquaculture (IAA) farming was aquaculture. In Vietnam, the well-known IAA was named as the "VAC" model [11]. Evolutionally, freshwater aquaculture recognized as a strategy in foods and foodstuffs sectors to improve nutritional standards as well as income generation to small-scale farming households [13,14].

Agricultural practices were absolutely predominant in Hai Duong where rice cultivation was still a traditional and principal source of staple food and income for the community farmers. Alternative land use and livelihood options such as aquaculture, fruit production and livestock were integrated components in farming activities which created more cash income, food and foodstuffs to meet daily subsistence needs [15]. To develop the regional economy, local authorities had planned to have a land conversion that some projected areas were spent to develop freshwater aquaculture production zones, of which, they before were used to be low paddy fields that had acknowledged being unproductive and inefficient due to hardly cultivating and unstably harvesting a crop at the duration of flooding season. Statistical data and records [16-18] in the region also indicated that the agricultural land was transformed rapidly into concentrated areas of aquaculture production which could provide availably more and more food and foodstuffs for this province (Figures 1-3).

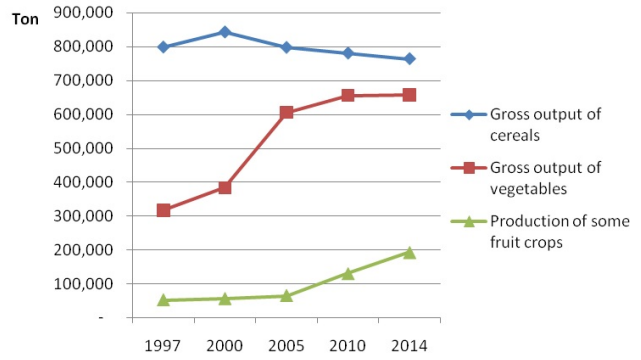

Figure 1: Changes in the gross output of different crop cultivation in Hai Duong (1997-2014).

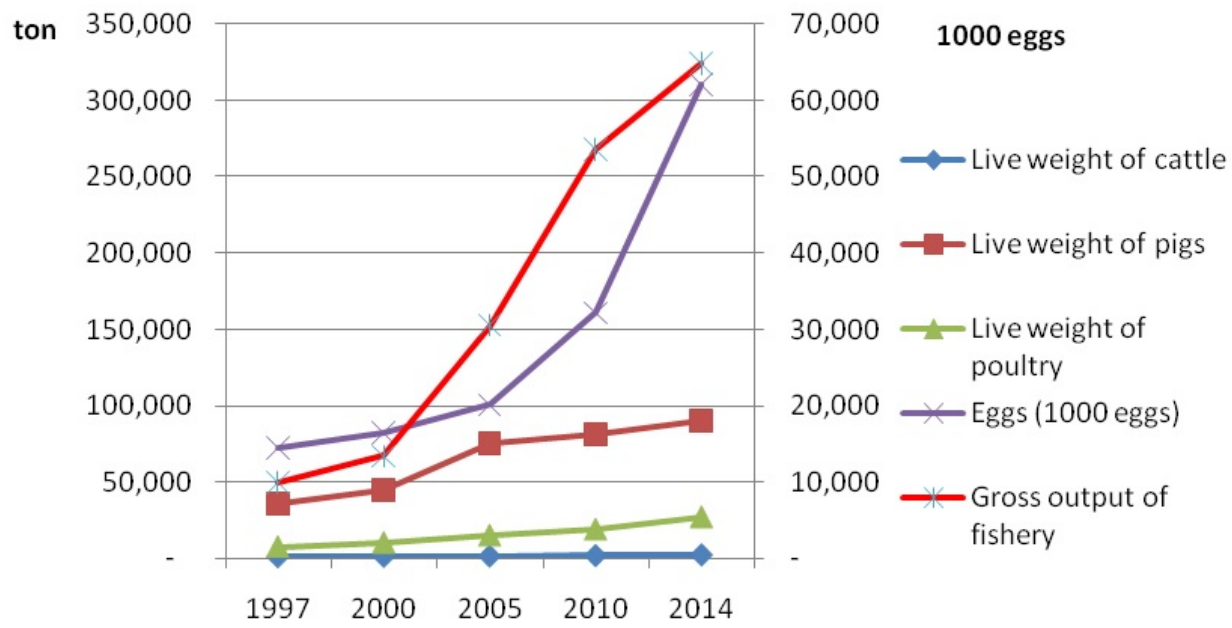

Figure 2: Changes in livestock and fish production in Hai Duong (1997-2014).

The increasing growth of fish production was thanking to the process on both intensification and extensiveness in the region. Here, the freshwater aquaculture production systems had a long history and had been very dynamic and diverse to not only on pond size, feed inputs, stocking, techniques and technology but also on the cultural experienced practices/ indigenous knowledge (farming combinations and relationship) within the agricultural activities. Thus, freshwater aquaculture was recognized to be as a key role in food and foodstuffs production systems in the province since its re-establishment in 1997. The statistical data showed that aquaculture area was the most expanded in the period 1997-2010 (Figure 3).

Last decades, there were a number of studies which mostly focused on the outcome of aquaculture production systems as health and nutritional sources to fish families and rural communities. They proved that the main benefits of freshwater aquaculture were directly consuming more fish by households and income generations which fish families could afford to purchase other foods cheaper in markets for improving their daily intakes [3,19-23]. In addition, the availabilities of fresh fish and employment creation also benefited to surrounding villagers and urban communities with cheaper prices and affordability to get the food by wages and salaries that generated from works, jobs in the supply chain of freshwater aquaculture industry related to input services; and output marketing activities.

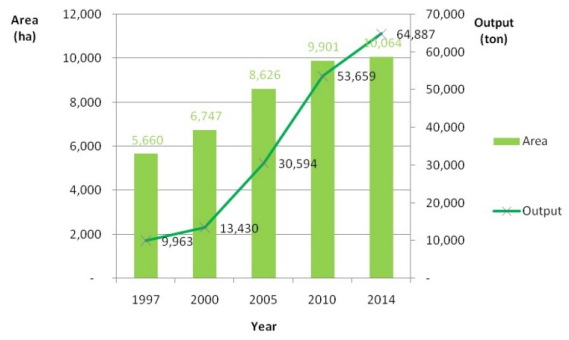

Figure 3: The Area and Production of Freshwater Aquaculture in Hai Duong province (1997-2014).

Freshwater integrated aquaculture systems were very dynamic and diverse from small to large-scale with market oriented products [24]. In Vietnam, at first, a typical system was named as the VAC system from which a large part of the systems produces was utilized for the household subsistence. For economic objectives, the systems were gradually developed market-oriented for improving the farmers' income. Thus, large number of produces was sold into markets for the farm families' cash income.

Misui et al. [25] identified fourteen types of farming enterprise combinations in the VAC system hereunder, VAC, VA, VC, AC, V, A, C, VAC+rice, VA+rice, VC+rice, AC+rice, V+rice, A+rice, and C+rice. The VAC classification was often improperly used by researchers and specialists in both Vietnam and Japan. The most appropriate approach to classify the VAC farming systems was base on agricultural income at household level.

Taking aquaculture's contribution into account in the discussion about food systems and rural development, it is, perhaps, not surprising that aquaculture production had been the most growth in Hai Duong province, since the 1980s. Statistical data showed that aquaculture production contributed approximately 2.7% (in 1996) and 12% (in 2014) [16-18] of the total production of agriculture in the province.

Sampling Design and Methodology

Primary and secondary data in the study were collected and analyzed qualitatively and quantitatively. The secondary data were provided by local government authorities, statistical agencies and institutions. The primary data was set up by two surveys of 167 fish farms at 04 villages in Hai Duong province (Table 1).

Location			Fish HHs	Animal/ Fish HHs	New VAC HHs	Traditional VAC HHs	Total
District	Commune	Village					
Cam Giang	Cam Doai	Hoa Binh	13	13	10	5	41
	Cam Dong	An Lai	8	18	9	3	38
Subtotal			21	31	19	8	79
Tu Ky	Hung Dao	Lac Duc	19	15	7	4	45
	Tai Son	Thuong Son	11	19	9	4	43
Subtotal			30	34	16	8	88
Total			51	65	35	16	167

Table1: Samples of fish households (HHs) selected in Hai Duong province.

Site selection and sampling design

Freshwater aquaculture in the Hai Duong was unique and quite notable thank to its entire geography located within inland territory (no coastlines) in the Red River Delta of Vietnam (Figure 4).

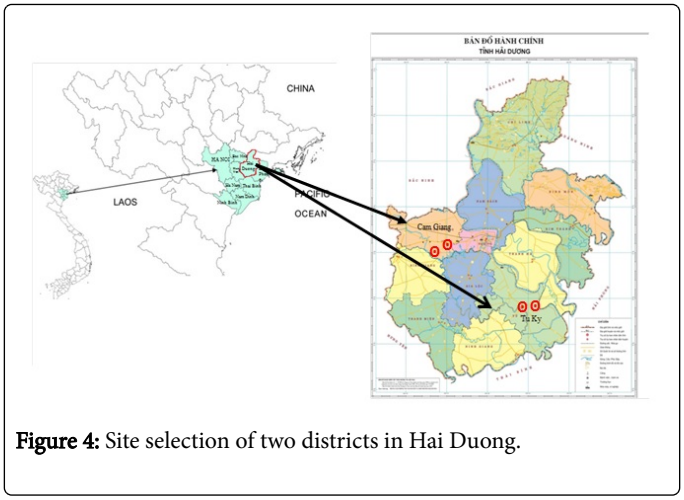

Figure 4: Site selection of two districts in Hai Duong.

Moreover, the province's fishery supposed to develop productively both in area and production. Here, the freshwater aquaculture production was unique, diverse and very dynamic. The VAC system was recognized to operate historically and prevalently in the region.

Since the freshwater production systems' data and information was limited in the survey site, two surveys were required for collecting the aquaculture systems' data and information. To conduct the first survey, three stages (at district, communal and village levels) were verified and defined the samples for the first survey in 2015. The outside residential area was chosen for the data collection. There were 151 fish farms were selected randomly from lists provided by local authorities, the heads of villages or cooperative and villagers (Table 1). The second survey was focus on fish production inside the residential area (villages) with the same protocol of collecting data and information in 2016. Because there were only a few farmers operating fish production inside their homestead inside the villages, 16 fish farms were finally found for the second investigation. Thus, 08 fish farms were interviewed at each district from the previous survey site.

Data analysis

It was multi-dimensionally analyzed the cross-relationships, linkages and combinations between aquaculture production systems to identify the principal factors, criteria within the existing aquaculture production systems. There were four systems defined both inside and outside villages: For inside village (1) farms with VAC practices-traditional VAC system; For outside village (2) farms with VAC practices-New VAC system; (3) farms with aquaculture and livestock husbandry practices-AF system; (4) farms with only aquaculture practice-FS system.

For further analysis of economic efficiency and effectiveness at household level, the calculations were adapted to use under the approach, criteria and indicators which were developed by McConnell [26]. The methodology was formulated to compare performance levels between agricultural farms (Table 2).

Measure	Calculation	Notes	Notes
A	All Outputs/Returns (Pooled)		
B	All Purchased Activity Direct Inputs (Pooled)		
C	All Farm Fixed Costs (except Depreciation)		Depreciation recorded in D below
D	All Capital Depreciation		
E	Farm Gross Margin	A-B	
F	Farm Net Actual Returns	E-C	Depreciation not yet charged.
G	Farm Net Sustainable Returns	F-D	Depreciation charged; system now sustainable.
H	Family Farm Available Income	H=F	But only if depreciation is not covered.
I	Family Farm Sustainable Income	I=G	Long-term Sustainable farm income.
J	Total Available Family Income	(H or I)+S	S is non-farm income, here assumed to be zero.

Table 2: Indicators and derived measures for annual whole-farm evaluation.

ANOVA was a statistical technique that assessed potential differences in a scale-level dependent variable by a nominal-level variable having two or more categories. The null hypothesis for an ANOVA was that there was no significant difference among the groups. The alternative hypothesis assumed that there was at least one significant difference among the groups. In the theory, the p-value associated with the F was smaller than 0.05, then the null hypothesis was rejected and the alternative hypothesis was supported. If the null hypothesis was rejected, one concluded that the means of all the groups were not equal. In addition, post-hoc tests were examined different groups from each other. However, there were several multiple comparison tests that could be conducted that would control for the type of error rate, including the Bonferroni, Scheffe, Dunnet, and Tukey tests [27-30].

Results and Discussion

Diversification of aquaculture production system

At first, to understand the context of aquaculture development in the HaiDuong province, at each village, 02 key informant group discussions were taken place to identify and classify the different aquaculture systems. The results were defined five main criteria of classifying the freshwater aquaculture production system at the study

site: (1) Location; (2) Integrated levels between sub-systems; (3) Farm household situations; (4) Animal husbandry; and (5) Horticulture. Thus, 04 prevalent aquaculture production systems were also recognized: (i) Intensive orchard very low input aquaculture within residential area-traditional VAC system; (ii) Intensive orchard-low input aquaculture outside residential area-New VAC system; (iii) Semi-intensive orchard medium input aquaculture outside residential area (Animal+Fish production)-AF system; (iv) Extensive orchard high input aquaculture (commercially intensive fish production)-FS system (Table 3).

FFPS	Location	Integrated levels between sub-systems	Farm household situations	Animal husbandry	Horticulture
Intensive orchard-very low input aquaculture (Traditional VAC system)	Inside village	High with closed available nutrient flow of food	Experience in aquaculture production, prevalence of rice production	With or without small pig production (1-5 pigs/HH), or small to medium scale poultry production	Small/medium number and area of perennial trees
Intensive orchard-low input aquaculture (New VAC system)	Outside village	High with closed nutrient flow of food	Less experience in aquaculture production	With or without small pig production (1-5 pigs/HH), or small to medium scale poultry production	Large number and area of perennial trees
Semi-intensive orchard-medium input aquaculture (Animal+Fish production-AF system)	Outside village	Medium	Experience in aquaculture and animal production	With or without medium pig production (10-50 pigs/HH) or commercial poultry production	Small number and area of perennial trees
Extensive orchard high input aquaculture (commercially intensive fish production-FS system)	Outside village	Low with more external supplement of food flow	Experience in aquaculture	Self-subsistence poultry production	Small number of perennial trees

Table 3: Freshwater fish production system (FFPS) characteristics in Hai Duong.

Most fish farmers outside residential area reported that they presently expanded their fish production base on their aquaculture experience and capital accumulation when they started to operate their small traditional VAC system before. The principal differences between the traditional VAC and New VAC were the scale of pond, levels of intensification and commercialization on their agricultural products and the locations (traditional VAC inside the village, and New VAC outside village).

Many fish farmers agreed that aquaculture production benefited their members of family and surrounding people with nutrition diet, employment creation, and income diversification. However, some farmers run their fish production as the FS system reported that their aquaculture production were quite susceptible to the risks of production and markets like the costs of inputs increasing continuously, particularly the price volatility of finished fish.

The study was conducted at the densely populated areas where producing mainly agriculture. Concentrated aquaculture productions were emerging to develop the local economy. The fish production's intensifications were range from extensive, semi semi-intensive to intensive levels. Extensive farming usually involved unsophisticated methods, relies on natural food and had a low input to output ratio. More intensification, fish was deliberately stocked and the natural food supply was enhanced by using organic and inorganic fertilizers, industrial feeds and low-cost feed supplements derived from agricultural by-products. It was found that there was no difference in stocking density between different aquaculture systems (stocking density around 1.5 fish in every m^2) in the survey site. Aquaculture development was most supported and expanded during the period 1997-2005 thank to interesting and projecting by both government and local authorities (Table 4).

Period	FS system	AF system	New VAC system	Traditional VAC system	Total
1980-1996	23	27	8	9	67
1997-2005	17	31	22	6	76
2006-2014	11	7	5	1	24
Total	51	65	35	16	167

Table 4: The start-up period of fish production at farms in Hai Duong.

In IAA systems, the essential characteristic is the flow of nutrients between enterprises, i.e. wastes from one enterprise become inputs to another in order to increase production. These wastes do not flow exclusively to the pond, but from the pond to other enterprises (in the form of pond mud and nutrient-rich water) such as in vegetable production around the pond. Some of these new enterprises and flows may only have been feasible through the introduction of the pond. Increased enterprise diversity provided opportunities for more nutrient linkages, and a possibility to meet increased nutrient requirements for enhanced production, although this required additional labour. This opened a path for on-farm or concurrent integration, both on small-scale farms and in large-scale commercial agri-businesses, with manure and fish production taking place on the same farm. At the community level, the diversification leaded to opportunities for o-farm

integration (i.e. between-farms), such as the sale of chicken manure by poultry growers to specialized fish farms.

The one-way ANOVA tests were checked to household size, paddy land, homestead land, agricultural land, number of fruit trees and the total head number of raised animals at the aquaculture production systems (Table 5). For the aquaculture production outside the residential areas, farms with New VAC systems had a largest number and area of fruit trees than that of other systems, but fewer fish ponds in their agricultural practices. For both inside and outside villages, the traditional VAC and New VAC system households' ownership of agricultural land was at the same size. The farms with AF system were characterized by large animal in combination with fish production.

	Unit	FS system (N=51)		AF system (N=65)		New VAC system (N=35)		Traditional VAC system (N=16)	
Age	Year	52.1	9.79	52.5	8.35	55.8	8.36	57	4.35
Household size	People	3.02*	1.09	3.80*	1.12	3.51	1.4	3.63	1.71
Number of labourers	Labour	2.45	0.92	2.86	1.1	2.66	1.45	2.63	0.96
Agriculture land	Sao(#)	18.7	9.1	18.3	7.76	11.7*	3.82	10.25*	3.17
Homestead land	m^2	353.0*	271	512.3*	430	459.5	228	320	109.42
Paddy land	Sao(#)	4.20*	3.48	6.17*	3.1	5.2	3.42	10.06*	3.32
Area of fruit trees	m^2	230	371	317.2	600	515.6*	878	131.25	76.58
Number of fruit trees	Tree	36	56	45	64.75	103*	171.2	17	7.85
Number of animals raised	Heads of animals	23	26.36	188*	234.4	39	36.01	64.69	17.86
Area of aquaculture land	Sao(#)	14.49*	9.58	12.12	7.01	6.51*	2.46	2.44*	0.63
Number of owned ponds	Ponds	2.27*	1.56	1.88	0.89	1.34	0.48	1	0
Experience in aquaculture	Year	16.5	7.23	17.6	7.27	14.1	4.85	17.31	2.02

(#) sao=360 m^2
(*) The mean difference is significant at the 0.05 level.

Table 5: The characteristics of fish farms in Hai Duong province.

Farmers operated traditional VAC system reported that their pond played an important role in their farming activities because it could combine effective utilization of available farm production resources by recycling the flow of nutritional products in the system, despite it was limited the production resources such as pond size, garden and other agricultural materials. With such resources, fish production was considered as the most important role for their agricultural activities beyond the income generation. Therefore, farms operating traditional VAC system were supposed to ensure their self-subsistence and food security, the strategy was still pursued by farms operated the New VAC system. Conversely, farms run AF or FS systems often sought the fish production for their income improvements.

Economic effectiveness and efficiency of freshwater aquaculture production systems

Farms operated VAC systems were really intensified and diversified. Investigated farms reported that poly-culture was almost applied for their fish production. In fact, number types of stocking fish were a bit more than those of other systems because they were really creative, indigenously expert and experienced to have better resource-utilisation of space pond (ex. the cycle of nutrient food-chain reuses) in their fish production. However, its stocking density was less than that of the AF and FS systems which was as a result of the commercially market orientation increasingly. In the latter systems, farmers often selected types of fish which were market valuable species that often stocked more intensively.

In farms run traditional VAC system, carp species was stocked prevalently in their fish production. It was harvested 12 months after stocking. The stocking density was from 1.51 fish in every square metre. The figure was calculated based on total grow-out fish pond. It was that because fish farmers normally used two or three ponds to rear continuously two or three stages during the whole cycle fish production. Observationally, the small pond was normally used to rear the fly/baby fingerlings or juvenile fish, the larger ones was continuously used next steps of the grow-out fish production. The annual fish production was from 885 kg to 4,727 kg/household. ANOVA tests showed that there was statistically significant difference to number and size of fish ponds among farms belonging to FS, New VAC; and traditional VAC systems (Table 6).

The economic effectiveness and efficiency of fish production by area of water surface was compared (Table 7). The All Purchased Activity Direct Inputs, available resources, returns and benefits related to fish production were presented by four above mentioned systems. The costs and benefits were simply calculated and estimated accordingly. Thus, only resources and available inputs that were tradable in the region were taken into account. It was worth of mentioning two interesting points about the findings with the farms operated the traditional VAC. The calculations showed that the system was the most labour intensive and the greatest usage of chemicals in the fish production.

	Unit	FS system (N=51)		AF system (N=65)		New VAC system (N=35)		Traditional VAC system (N=16)	
Area of aquaculture	Sao	14.49*	9.58	12.12	7.01	6.51*	2.46	2.44*	0.63
Number of ponds	Ponds/ household	2.3*	1.56	1.9	0.89	1.3*	0.48	1	0
Production cycle time	Months	9.8	2.59	10.5	1.88	10.7	2.03	12	0
Stocking density	Fish/m^2	1.55	1.11	1.62	1.15	1.49	0.89	1.51	0.35
Kinds of fish	Fish/stocking	4.31	1.22	4.37	1.18	4.31	1.39	6.13	0.88
Production	Kg/household	4,727	4176	4,254	2,475	2,144	1,233	885*	286
Yield	Kg/sao	325	166	359	176	339	164	373	384
(*) The mean difference is significant at the 0.05 level									

Table 6: The status of fish production at farms in Hai Duong province.

Firstly, the traditional VAC system was the most labour intensive system in the fish production. The reasons were explained by scale effect, types of stocked fish, and calculation errors. It was the fact that farms operated the traditional VAC system often owned a small scale of fish pond (2.4 sao). In addition, the types of reared fish were often chosen to stock objectively to be the most utilities or traditional/easily-rearing fish like grass carp, silver carp of which feeds were grass, natural plants or some types of ephemeras... that were mostly materials or feeds requiring totally manual preparation. In addition, it was hard to calculate accurately this figure in the study because farmers often were not sure or did not remember accurately the working time they spent on fish farming. Lastly, fish pond was nearby their homestead so that they took so much time for many other jobs like caring the animal, watering vegetables and pile of housework's. Therefore, the system's aquaculture was admitted to be the most labour intensive.

	FS system (N=51)	AF system (N=65)	New VAC system (N=35)	Traditional VAC system (N=16)
Global HH production(kg)	4,727	4,254	2,144	885
HH production/sao (kg)	325	359	339	373
Home consumption (Kg)	11.9	13.5	27.9	52.9
Total value of fish for home consumption	502.1	602.6	1,199.00	1,452.70
Total value of fish sold	13,336.70	15,610.20	15,100.80	9,638.80
Total value of fish	17,720.70	20,537.00	20,140.80	13,312.80
All variable costs 2 (All Purchased Activity Direct Inputs)	8,349.90	9,797.20	9,305.80	5,263.40
Fingerlings	2,202.90	2,577.50	2,995.20	1,523.50
Feed	5,622.30	6,441.10	5,641.20	2,823.70
Fertilizer	3.6	1	9.4	-
Lime	92.8	109.7	84.5	107.7
Chemicals	242.5	283.6	208.2	323.9
Energy	187.6	335.7	338.7	253.1
Other	48.6	48.7	28.5	231.6
Gross Margin of Fish	9,370.90	10,739.70	10,835.20	8,049.40
All Farm Fixed Costs (Except Depreciation)	172.5	193.2	272.9	231.3
Farm Net Actual Returns	9,198.30	10,546.50	10,562.30	7,818.30
All Capital Depreciation3	602.7	886.3	755.1	701.6

Farm Net Sustainable Returns of Fish	8,595.60	9,660.30	9,807.20	7,116.70
Working Labour (man-days)	14	16.4	32.6	49.6
(1) Exchange rate: 1 USD=22.500 VND				
(2) The cost is excluded the family labour				
(3) The fixed cost is calculated based on depreciation over 10 years				

Table 7: Economic Effectiveness and Efficiency of fish production per Sao at Farms in Hai Duong province.

Secondly, the chemical (324 thousand VND per sao) was greatly used by farms operated the traditional VAC. It was because of the inefficient utilization, small-scale effect, and environmental requirements among the compared aquaculture systems. The ownership of small pond often required fish farmers to buy a bottle of chemical product for their fish farming, however, it was not used the full bottle for the fish production. Investigated farmers reported that in many cases, the rest of chemical was used for other agricultural activities like animal production, rice, vegetables, and/or loss due to its spoiled quality or over expiry date. On the other, the pond was nearby the homestead inside the residential area/village where wastes, sewage originated from villagers' daily activities were believed to let out. To maintain the fish production, fish farmers normally selected the kind of bio-chemical to treat the fish pond. They were obviously expensive chemicals in the markets. A question was asked to the traditional VAC farms why they selected these expensive bio-chemicals for using the aquaculture production. The answer was that the usage of the bio-chemicals could help them a safe fish and better environment protection. Fish farmers also believed it as the unique and/or sustainable solution for their maintaining fish production under circumstances of the problematic environment surrounding the fish pond.

It was noticeable that the most efficient system was New VAC with Farm Net Sustainable Returns of Fish (9,807 thousand VND or 435 USD per sao). This system, currently, was most being interested and projected to develop by not only government authorities but also rural farmers in Vietnam.

Contribution of freshwater aquaculture to the food system and rural development

The off-farm income was not taken into account in the study so that average total farm's income consisted of values from rice cultivation, animal husbandry, aquaculture, vegetables, and orchard garden. The largest income belonged to the farms operated AF system with 100 million VND (equivalently more than 4,400 USD) annually. Farms operated the traditional and New VAC systems had a similar income that was lower than that of AF and FS systems. This was due to their limited agricultural land, capital investment, and some related resources in comparison to the latter systems. With Kruskal-Wallis tests, it was not found any significant differences between the economic benefits of these systems (Table 8).

	FS system		AF system		New VAC system		Traditional VAC system	
	(N=51)	%	(N=65)	%	(N=35)	%	(N=16)	%
Rice crop	5,265.40	64.5	8,171.30	62.4	6,818.20	46	13,729.10	75.6
Vegetable crop	-	-	1,380.40	10.54	1,053.30	7.1	2,189.60	12.1
Fruit crops	2,901.80	35.5	3,544.00	27.06	6,958.00	46.9	2,238.30	12.3
Total crops	8,167.10	11.3	13,095.80	12.99	14,829.50	25.6	18,157.10	31.1
Livestock husbandry	4,904.60	6.8	34,162.40	33.87	8,077.90	13.9	29,243.00	50.1
Fish production	58,922.80	81.8	53,594.10	53.14	35,024.80	60.4	10,997.60	18.8
Total	71,994.50	100	1,00,852.30	100	57,932.10	100	58,397.70	100

Table 8: Sources of on-farm income at fish farms in Hai Duong province.

It was the fact that the total on-farm income was not considerably improved, farms operated the traditional VAC still had the largest income from rice cultivation thanking to preserve most of their agricultural land for the rice production. Additionally, the system's livestock husbandry income (29,243 thousand VND or 1,300 USD) was larger than that of New VAC system because less input of commercial feeds was used. Utilizing the household's own resources (the VAC system's products and agricultural by products) was preferred effectively and efficiently. This was very important and significant point to state that the traditional VAC system would be a sustainable food supply model. The farming system was believed to help Vietnam overcoming the miserable food insecurity in 1980s when the country was inadequate of food and foodstuffs.

Furthermost, rice was a staple crop in Vietnam which was culturally consumed by people. Vietnamese government had been projected to retain about 3 million ha for rice production under the national

program of food security. Thus, it was meaningful that farmers still retained the large number of agricultural land for the rice production. In addition, by operating the system, the farmers could self-supply diversely not only different food and foodstuffs but also income diversity. Particularly, responding to the question: what did they think about their aquaculture systems? Most traditional VAC and New VAC farmers confidentially answered that they were happy with their situation of economic stabilization and food security; whatever they sometimes witnessed their neighbours operated FS or AF systems obtaining a valuable harvest of fish production.

Conclusion

Over time, freshwater aquaculture production systems were dynamic, diverse and subject to economic and environmental changes. The development of aquaculture in the Red River Delta had shown the evolution from low-input on-farm integrated systems to high input o-farm integrated and commercial systems, supplying significant amounts of fish to rural and urban consumers. The aquaculture production systems played a key role in the development and diversity of food systems. This was clear evidence that these fish production systems, especially Integrated Agriculture Aquaculture-traditional VAC, New VAC and AF systems were becoming more and more important in northern Vietnam for food security and rural development.

FS system was less efficient and stable in terms of resource-utilization and economic benefits (production and market risks). With similar levels of farm resources or capital investment, farms operated the AF system was able to obtain a much monetary return than that of farms belonging to the FS system. In addition, there was the most economic efficiency and effectiveness at farms operated the traditional VAC and the New VAC systems. This persuasively supported VAC model likely to be a sustainable food system in developing countries, particularly, in the context of rapid agricultural land loss which was transformed to develop the urbanization and industrialization in Vietnam. The system could answer the debate question: What would be the sustainable food production system in the future? Which one would feed the growing population with smaller and smaller areas of cultivated land?

Farms operated the traditional VAC system still preserved an enough area of agricultural land for their rice production. This was fundamental basis for any Asian populated countries with cultural consumption of rice daily to ensure its food security not only in short term but also long term. In addition, with the system, farmers could easily diversify their farming practices, food, foodstuffs, redundant employment, and income. Particularly, with income diversification, farms could reduce the vulnerability on their agricultural practices both on production and market.

Furthermore, poor people in rural might also benefit from the provision of low-cost fish. If it was well planned and managed, VAC farming could significantly contribute to the process of hunger eradication and poverty alleviation, especially safeguarding against environmental pollution in agricultural production with huge by-products and wastes.

Finally, in the developing countries like Vietnam, food security (utilization and availability aspects) is still problematic. Where the VAC system, typically the traditional VAC system, would be considered and targeted to maintain and/or support as a sustainable food supply model against the food insecurity.

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