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New Freshwater Aquaculture Systems in the Red River Delta of Vietnam: Evolution of a Key Role in Food Systems and Rural Development

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Abstract

Freshwater aquaculture production systems are closely related to Integrated Agriculture Aquaculture systems. The systems are traditionally integrated with crop production, horticulture, and livestock husbandry. Improved aquaculture systems are currently able to not only improve the nutrients of local farmers' diets and economic conditions, but are also able to create employment opportunities and lead to better resource-utilization and rural development. This paper aims to present the changes in food systems affected by the rapidly developing freshwater aquaculture in northern Vietnam. It will shed light on how the aquaculture system plays various roles in supporting agrarian livelihoods, their relationships to well-being, and food security using a clear example of small-scale aquaculture in a province of the Red River Delta. The challenges and opportunities presented to small-scale producers and culture systems are assessed, and the likely future of small-scale freshwater production systems is discussed and forecast.

Combining historical, adaptive, and systematic approaches, the study revealed the features and characteristics of inland aquaculture systems at the household level over a decade of the evolutionary process (1997–2015). By investigating 151 aquaculture households in two representative districts of the region, the three existing systems are identified: VAC system (23%) (whereby V=vuon-gardens (horticulture), A=Ao-ponds (aquaculture) and C=Chuong-animal

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sheds/pens (livestock husbandry)); aquaculture/livestock (AF) system (43%); and the commercially intensive fish culture (FS) system (34%). Beyond the positive benefits to the food system and rural development, potential considerably exists for further aquaculture integration within VAC systems in the region, which will contribute to poverty reduction and improvement of the livelihoods of small-scale rural farmers.

Keywords: Freshwater aquaculture, production, systems, food, rural development

Resumen

Los sistemas de acuacultura de agua dulce están muy relacionados con los sistemas integrados de acuacultura de agricultura. Los sistemas están tradicionalmente integrados con la producción de plantaciones, horticultura y la cría de ganado. Los sistemas de agricultura mejorada pueden actualmente no solo mejorar los nutrientes de las dietas de granjeros locales y las condiciones económicas, sino que también pueden crear oportunidades de empleo y llevar a una mejor utilización de recursos y desarrollo rural. Este documento busca presentar los cambios de sistemas alimenticios causados por la acuacultura de agua dulce que se está desarrollando rápidamente en el norte de Vietnam. Resaltará cómo el Sistema de acuacultura juega varios papeles para apoyar la subsistencia de los agricultores, sus relaciones al bienestar y la seguridad alimenticia al utilizar un claro ejemplo de acuacultura a pequeña escala en una provincia del delta del Río Rojo. Los desafíos y oportunidades que se le presentan a los productores a pequeña escala y a los sistemas culturales son evaluados, y el futuro probable de los sistemas de producción de agua dulce a pequeña escala se discute y predice.

Al combinar los acercamientos históricos, adaptativos y acercamientos sistemáticos, el estudio reveló las funciones y características de los sistemas de acuacultura en zonas interiores, a nivel de hogar y a lo largo de una década del proceso evolutivo (1997-2015). Al investigar 151 hogares acuacultores en dos distritos representativos de la región, los tres sistemas existentes se identifican: Sistema VAC (23%) (donde V=jardines Vuon (horticultura)), A=estanques

Ao (acuacultura) y C=establos de animales Chuong (cría de ganado)); Sistema (AF) de acuacultura/ganado (43%); y sistema de cría de peces comercialmente intensiva (FS) (34%). Más allá de los beneficios positivos del sistema alimenticio y desarrollo rural, existe un potencial considerable para más integración de acuacultura dentro de los sistemas VAC en la región, que contribuirá a la reducción de pobreza y el mejoramiento del sustento de granjeros rurales a pequeña escala.

Palabras clave: Acuacultura de agua dulce, producción, sistemas, alimentación, desarrollo rural

摘要

淡水养殖生产系统和一体化农业水产养殖系统紧密联系。这些系统一般都和谷物生产、园艺以及畜牧业合并在一起。改进后的水产养殖系统不仅能提高当地农民的膳食营养和经济情况，还能创造就业机会，并引导更好的资源利用和农村发展。本文致力呈现越南北部因淡水养殖急速发展而产生的粮食系统变化。本文将红河三角洲范围内一个省的小规模水产养殖作为案例，清晰阐述了水产养殖系统如何扮演不同角色，为农业生计、农业生计与安乐的关系、以及粮食安全提供支持。本文评估了小规模生产者和养殖系统面临的挑战和机遇，探讨并预测了小规模淡水生产系统的未来。

本文结合历史方法、自适应方法和系统方法，揭示了内地家庭水产养殖系统经过十多年演变后的特点（1997-2015）。通过调查两个代表区中的151户水产养殖家庭，识别了三种现有系统，它们分别是：VAC系统（V=vuon-gardens，即园艺，
A=Ao-ponds，即水产养殖，C=Chuong-animal，即畜牧业），占比23%；水产养殖/畜牧（AF）系统，占比43%；商业性强的鱼类养殖（FS）系统，占比34%。水产养殖除了给粮食系统和农村发展带来积极益处，未来还很有可能在该区域VAC系统中进一步合并，这将促进减少贫困，提高小规模农民生产者的生计。

关键词：淡水养殖，生产，系统，粮食，农村发展

I. Introduction

Freshwater aquaculture is 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 (Dey & Ahmed, 2005; Dey et al., 2005; Mishra & Ray, 2009; Prein & Ahmed, 2000; Tacon, 1997). Belton and Little (2011) predicted that the aquaculture production systems would become more intensive and uniform and output will, on the one hand, satisfy the growing demand of mass markets for safe animal-source products but, on the other, is unlikely to meet the strong cultural attachment to the diverse and local that is still prevalent in rapidly growing areas of Asia, where the cultural value was characterized as traditional and often "wild" foods. This resilience of food cultures would be possible to anticipate the continued existence of considerable market demand for small-scale producers. The rapid growth and widespread development of aquaculture have been occurring at a critical time in human history, especially increasing unpredictability associated with climate change and greater volatility in food prices and food security would be a reality. Climate change would be expected to bring particularly severe impacts to the densely residential deltas of Asia where small-scale aquaculture is most prevalent and where, if maintained or further developed, it might be responsible for an important role in adaptation approaches oriented to enhance social–ecological resilience.

In Vietnam, freshwater fish contributes to 12.4% of the 29 g capita^{-1} day^{-1} animal-based protein supply (FAO, 2013), of which 37% is supplied by the cyprinid and cichlid species and mainly produced through aquaculture (FAO, 2011). It has been widely recognized that farm product diversification through aquaculture can contribute to a sustainable method of developing food security, alleviating poverty (Edwards, 2000; Prein & Ahmed, 2000; Tacon, 1997), and also may increase resilience to financial shocks in developing countries such as Vietnam. Promoting the aquaculture separate from, or integrated within, broader livelihoods therefore becomes a crucial policy issue. Aquaculture has, in some cases, been inherent in national poverty reduction strategy plans or has become a key part of macro-economic growth. The renewed approach in which various types of aquaculture can contribute to poverty alleviation at household, community, and national levels is critical (Little et al., 2010). Although aquaculture farming has greatly improved in the past decades, few studies have focused on the entire range of benefits within the existing systems of freshwater aquaculture production in the Red River Delta region.

In diverse and highly populated regions in Asia like China and northern Vietnam have a long and acknowledged history of freshwater aquaculture production systems (Edwards, 1993; Luu, 2001; Ruddle & Zhong, 1988), suggesting that aquaculture is the key component of Integrated Agriculture Aquaculture (IAA) farming, commonly known as the "VAC" model. This acronym is derived from the Vietnamese words for orchard (vuon), pond (ao), and livestock pen (chuong), and was the farming system become popularly to exploit in the 1980s in order to project and to expand food security strategies. The VAC system's success among the local and rural people in terms of food security pushed the Vietnamese government to implement the Sustainable Aquaculture for Poverty Alleviation (SAPA) strategy and to carry out the Programme of Hunger Eradication and Poverty Reduction (Luu, 2002). Initially, the system was introduced in the Red River Delta area and then became widespread and developed in other regions. As a result, freshwater aquaculture became a strategy in sub-sectors to improve nutritional standards and to generate income in small-scale farming households (Luu et al., 2002; Pekar et al., 2002).

In Hai Duong, a central province of Red River Delta in northern Vietnam, rice cultivation is still the traditional and principal source of income for farmers. Alternative land use and livelihood options such as aquaculture, fruit production, and livestock (Hanh, Ton, & Lebailly, 2013) are integrated components in farms and create more cash income, food, and foodstuffs in order to meet subsistence needs (Lebailly et al., 2015). In this province, the targeted areas to develop freshwater aquaculture were those large lowland areas of rice fields which had low productivity and were being inefficiently utilized due to unstable crops during the flooding season. Statistical data and records indicate that, by 2014, the land used for aquaculture had expanded rapidly, increasing by 64% from 5,668 ha in 1996 (Hai Duong Statistics Office, 1999, 2014). Government policy strongly supported these changes. Since 1999, the Vietnamese government and local authorities have promoted the restructuring and diversification of the agricultural sector with the goal of reducing the share of rice in the total agricultural output value while increasing the contribution of aquaculture to economic growth. This policy resulted in the growing importance of aquaculture and is reflected in the following figures: in 1996, aquaculture production contributed approximately 2.7% to the total gross production of agriculture in Hai Duong and in 2014, it made up 12%. Between 1997 and 2014, aquaculture production increased annually by 13% and in surface area by 3.9% annually (Hai Duong Statistics Office, 1999, 2014).

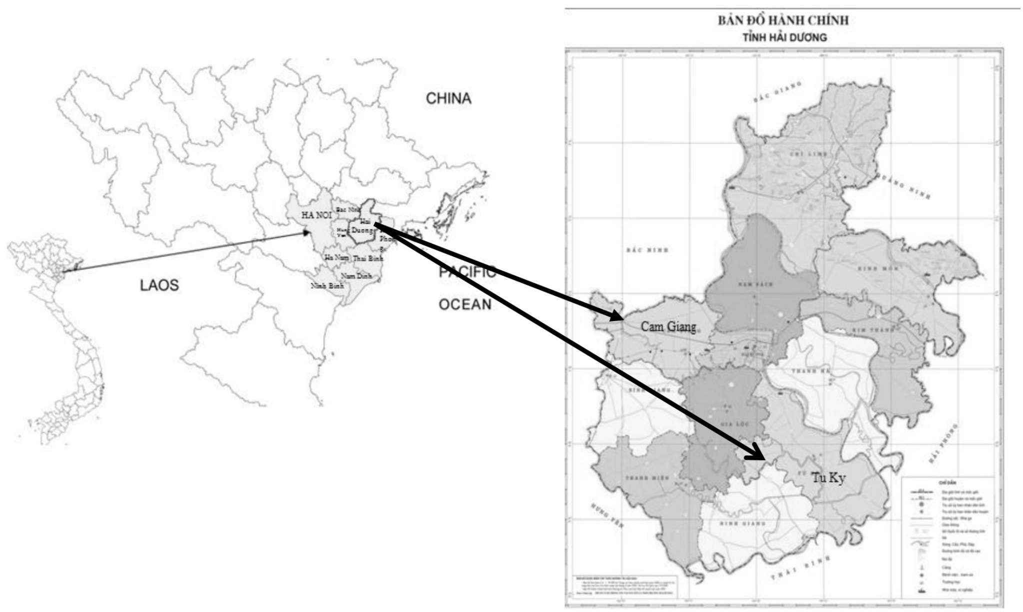
II. Methodology

As qualitative and quantitative methods were employed in this study, the secondary data were gathered from the local statistical offices and annual records at the survey sites. In addition, primary data and information (group discussions and household interviews) were used for the research analysis of household aquaculture data, including information such as general characteristics of households, their aquaculture systems, integrated farming activities, and on-farm income sources related to the fish farming. The data collection and analysis were implemented as follows:

Site selection and sampling design

Central location in the Red River Delta (see Figure 1), Hai Duong province's fishery has, recently and quickly, been developed in both surface area and output. Because this province is situated entirely inland (with no coast), only freshwater aquaculture and the VAC system can be found and were developed early in northern Vietnam—the Red River Delta, its freshwater aquaculture tends to be unique and quite notable.

Figure 1. Site Selection of Two Districts in Hai Duong



Source: Vietnam department of survey and mapping 2015.

Although, over the decades, freshwater aquaculture has been projected to develop in the province, there has been limited data and information or studies about the freshwater production systems. It is also quite difficult to define and verify the classification, category, and characteristics of the aquaculture production systems existing at the research site. Therefore, three stages were applied in order to design the sampling. First of all, the two districts of Tu Ky and Cam Giang were selected in order to investigate the aquaculture households because of their strongly developed and diverse fish production systems. Secondly, two communes were identified from each district. Finally, the more prevalent fish-rearing village was chosen from each selected commune.

Table 1. Samples of Fish Households (HHs) Selected in Hai Duong Province

Location			Fish HHs	Animal/ Fish HHs	VAC HHs	Total
District	***Commune***	***Village***				
Cam Giang	Cam Doai	Hoa Binh	13	13	10	36
	Cam Dong	An Lai	8	18	9	35
Subtotal			***21***	***31***	***19***	***71***
Tu Ky	Hung Dao	Lac Duc	19	15	7	41
	Tai Son	Thuong Son	11	19	9	39
Subtotal			***30***	***34***	***16***	***80***
Total			**51**	**65**	**35**	**151**

The sampling design was defined from the selected villages, of which 151 households with fish farming were randomly selected from the lists that were provided by local officials and authorities such as leaders of The People Committee, Cooperatives, and/or Villages. The sampling design is described in Table 1. The number of households was 39 from Thuong Son; 41 from Lac Duc; 36 from Hoa Binh; and 35 from An Lai village.

Data analysis: Multivariate factor analysis was employed to analyze the cross-relationships between aquaculture production systems in order to identify any major underlying factors between these relationships. Three models were established: (1) first for households with VAC farming—VAC system; (2) second for those engaged in aquaculture and livestock husbandry—aquaculture/livestock (AF) system, and the (3) third for commercially intensive fish culture farms—FS system.

According to McConnell and Dillon (1997), the farm analysis was based on the collected data and farm records or received as estimates from memory of members of the household. In reality, the production/disposal data are activity-specific, but the inputs/costs are "all mixed up" with no indication of which inputs have been used for which activities. However, the study protocol managed to obtain a picture of the farm operation as a whole. On the other hand, on small farms, it is usually necessary to distinguish between different classes of outputs: final products that are sold or consumed by the household and intermediate products used in another farm operation as resources. For subsistence-oriented farms, it is necessary to impute the prices/values of products which are not sold for cash. Therefore, the values of all final products (A—All Outputs/Returns) are consolidated as a total gross return for the household and all direct input costs (B—All Purchased Activity Direct Inputs) of all activities are also consolidated to give a total direct cost. This excludes the value of farm-generated resources. There are General Charges and Capital Equipment Repairs, Operation (C—All Farm Fixed Costs), which are recorded as part of the Total Farm Fixed Costs.

Table 2. Indicators and Derived Measures for Annual Whole-farm Evaluation

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.

Source: McConnell and Dillon (1997).

The Total Farm Gross Margin is the easiest to derive: it consists of the sum the gross margins of all activity, or if activity costs/returns have been pooled, the total value of farm output of final products minus total farm direct costs. If required, this is a good measure of performance to compare similar farms supposing their capital structures (levels of fixed costs) are similar or relatively unimportant. An alternative measure is to use the index of Farm Net Returns. But this level of "income" is not stable over the long term because it makes no provision for replacing capital equipment as it wears out. If this is an important consideration, the Farm Net Actual Returns should be decreased by the depreciation charge in order to obtain the Farm Net Sustainable Returns.

In this study, the analysis measured terms of farm performance from records in the following areas: Farm Gross Margin (E), Farm Net Actual Returns (F), Farm Net Sustainable Returns (G), Family Farm Available Income (H), Family Farm Sustainable Income (I), and Total Available Family Income

(J). While these indicators are desirable because E, F, G, H, I, and J are adequate records and over time to indicate the degree of variability in the performance of the subject farm, they do not in and of themselves provide any basis for comparing a farm's income levels to those of other farms. If whole-farm comparison is introduced at this point, the results are summarized in Table 2. Thus, fish farms would be compared in terms of the measures E, F, G, H, I, J with other farms in the village or area having a similar size, soil, water supply, etc. but not necessarily the same mix of activities.

III. Research Results and Discussion

A Key Role of Aquaculture in the Food Production System

To understand the context of aquaculture development, group discussions were used to identify the basic features and characteristics of the existing freshwater aquaculture production systems in the survey areas. The findings showed that fish farms usually have three components: (1) the homestead and perennial trees (fruit orchards created by pond dikes), (2) the pond, and (3) the rice field. The livestock, fruit orchards, and the pond are usually located together. The homestead area consists of livestock, fruit orchards, vegetables, and other trees which are located close to the residence, with an average area of around 433 m^2. In addition, the link between the components, the scale of livestock production, area and number of fruit trees, and the household's economic status as well as their experience in fish production were determined (see Table 3).

It was reported by the households with animal/fish production (AF systems) and commercially intensive fish production (FS) systems that their fish cultures in the past originated with the traditional homestead VAC model which, to a certain extent, has disappeared. However, the modern VAC and other systems still exist due to the number of farmers who believe strongly that the current VAC model has been restructured by increasing and balancing its economic scale level of components, namely fish pond size, orchards, and animal husbandry. VAC households are, thus, not characterized as aquaculture ventures. On the other hand, most farmers belonging to AF or FS household groups answered that they were able to develop their fish production thanks to the accumulation of knowledge and experience in aquaculture, as well as capital investments from establishing the traditionally small VAC model.

The benefits of aquaculture in food systems within the context of rural development relates to health and nutrition, employment, income, the reduction of vulnerability, and farm sustainability. In the municipal survey, the freshwater aquaculture systems provide high-quality animal protein and essential nutrients, especially for nutritionally vulnerable groups such as pregnant and lactating women, infants, and pre-school children. In particular,

Table 3. Freshwater Fish Production System (FFPS) Characteristics in Hai Duong

FFPS	**Integrated levels between sub-systems**	**Farm household situations**	**Animal husbandry**	**Horticulture**
Intensive orchard—low input aquaculture (New **VAC**)	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**)	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 (**Commercial fish production—FS**)	Low with more external supplement of food flow	Experience in aquaculture	Self-subsistence poultry production	Small number of perennial trees

Source: Discussion with key informants in the research site, 2015.

it also provides protein at prices generally affordable to the poorer segments of the community. Most survey households responded that fish ponds have created an enterprise for self-employment, including jobs for women and children, and creates income through the sale of surplus aquaculture products. Income from employment opportunities are also possible for the people who work for larger farms, in seed supply networks, market chains, and manufacture/repair supporting services. Indirect benefits include increased availability of fish in local rural and urban markets, which leads to an increase in the local consumption of fish.

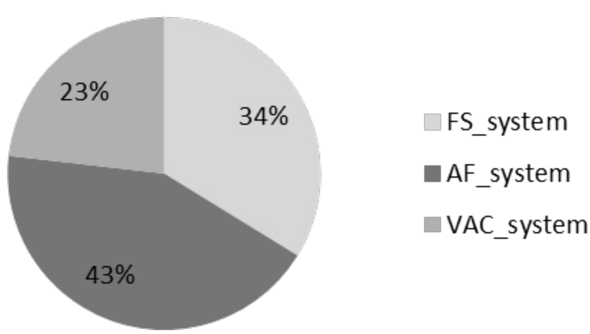
The inland aquaculture systems in Hai Duong can shed light on the previous observation of Prein (2002) that integrated aquaculture systems are diverse and have a wide range of small- to large-scale systems that are fully oriented to the market. For small-scale VAC systems, part of the production is used for subsistence purposes with some level of market involvement or communal exchange. In such systems, aquaculture enterprises are only a minor component of the farm as a whole. However, with greater farm specialization and market orientation, aquaculture enterprises could become a dominant feature. This supposes a key role of aquaculture in food production systems in the future.

Classification and Structure of Freshwater Aquaculture Production Systems

Misui and Horiuchi (2006) indicated that the Vietnamese government misuses a criterion of agricultural sales that would be suitable in developed countries like Japan and misclassifies VAC farming systems in the Red River Delta. These farming systems have 14 types of farming enterprise combinations, i.e. VAC, VA, VC, AC, V, A, C, VAC+rice, VA+rice, VC+rice, AC+rice, V+rice, A+rice, and C+rice. The systems can be classified by many optimum criteria, the most appropriate of which in VAC farming systems is agricultural income, classified by self-sufficient farm households in Vietnam.

In populated rural regions like Hai Duong, extensive to semi-intensive aquaculture systems are prevalent and produce the bulk of aquaculture products. Extensive farming usually involves unsophisticated methods, relies on natural food, and has a low input to output ratio. As production intensity increases, fish are deliberately stocked and the natural food supply is enhanced by using organic and inorganic fertilizers, industrial feeds, and low-cost feed supplements derived from agricultural by-products. The survey results showed extensive and semi-intensive (stocking rate less than 1 fish/m^2) aquaculture production systems in the region. However, based on the aquaculture integration to agriculture patterns, or IAA system, the structure of aquaculture production systems is determined by analyzing the household survey. The number of households applying the improved VAC system accounted for 23%, the animal/fish (AF) production system made up of 43%, the largest percentage, and 34% for the commercially intensive fish production (FS) system (Figure 2).

Figure 2. The Structure of Freshwater Aquaculture Production Systems in Hai Duong



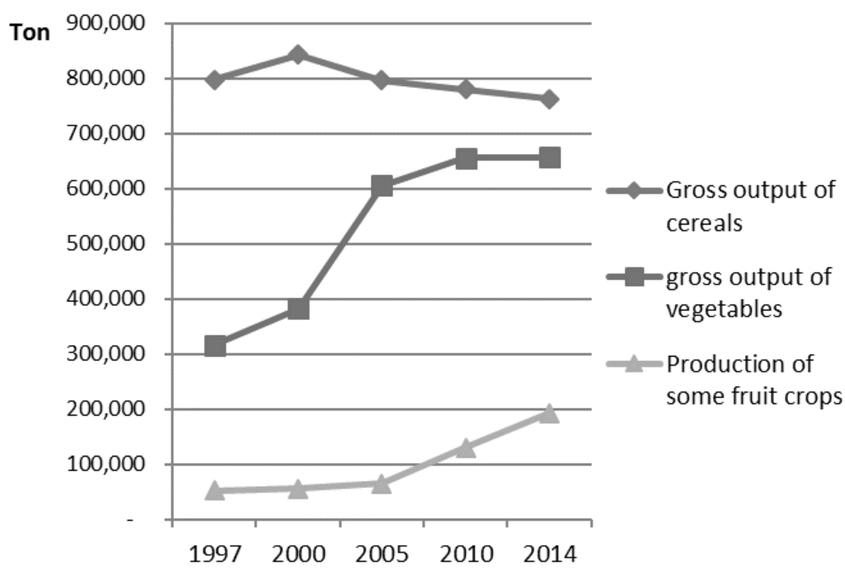
Source: survey, 2015.

The Evolution of Freshwater Aquaculture in Food Production Systems

In recent years, the food production system in Hai Duong has changed significantly. In spite of engaging principally in farming activities, the output of cereal production showed a downward trend before increasing to 842,826 tons in 2000. In contrast, vegetable and fruit crops, livestock production, and fish production grew positively in their annual gross outputs. These outcomes resulted from the strong movement to develop the VAC systems' components in the province (see Figures 3 and 4). Along with this process, the traditional VAC system (model) has been modified and improved in other "hybrid" aquaculture systems in which fish ponds, livestock, and orchards have moved from the residence areas to the rice field areas and developed a more commercial orientation under the impact of urbanization and socio-economic changes.

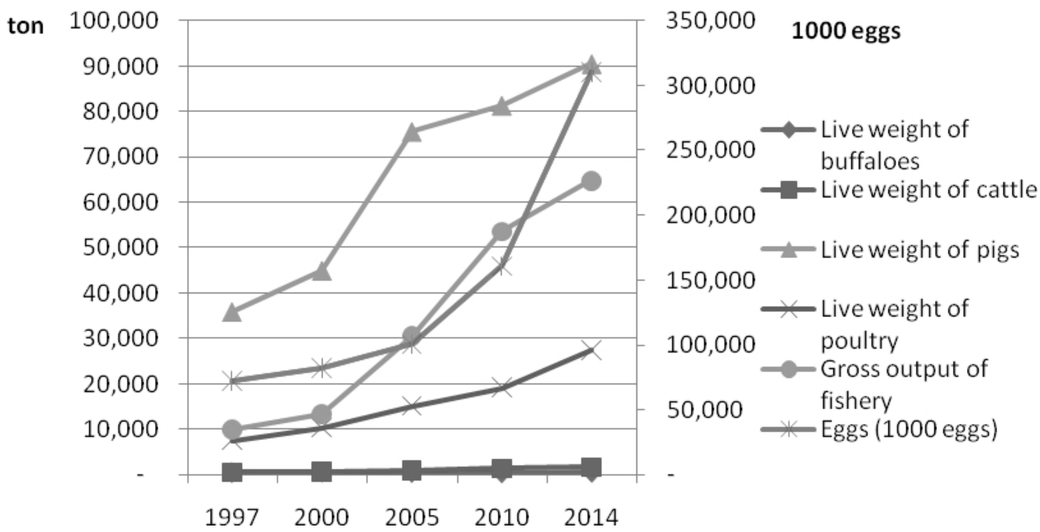
The traditional VAC model was understood and initially developed in 1980s, although it was not a far-reaching system with closed nutrient food flows. In just over a decade, the achievements of the system were undeniable; it provided a large quantity of food and foodstuffs to farmers in rural areas. Thus, the statistical data, records, and information prove that the gross output of vegetables and fruit crops rose also from 315 and 51 thousand tons in 1997 to 657 and 192 thousand tons in 2014, respectively; and this was in addition to strongly developed animal husbandry

Figure 3. Changes in the Gross Output of Different Crop Cultivation in Hai Duong (1997–2014)



Source: Hai Duong Statistics Office.

Figure 4. Changes in Livestock and Fish Production in Hai Duong (1997–2014)



Source: Hai Duong Statistics Office.

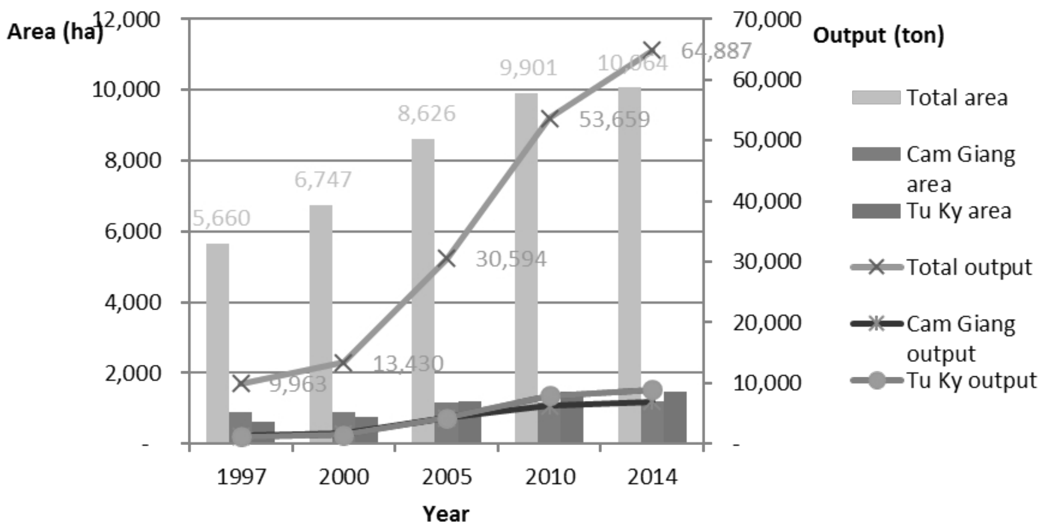
practices. The availability of eggs greatly increased as well, going from 72.5 million in 1997 to 310 million eggs in 2014 (Hai Duong Statistics Office, 1999, 2005, 2014). This period also witnessed a sharp increase in the output of pig and poultry production from 35,895 and 7,524 tons in 1997 to 90,575 tons and 27,421 tons in 2014, respectively.

The current trend increases fish production by intensifying and expanding the areas under aquaculture production, and this trend can be maintained and encouraged. Generic technologies used to intensify the existing production systems are in place, and it is mainly socio-economic and institutional issues that will significantly foster greater contributions from aquaculture to rural development. In Hai Duong, the freshwater aquaculture production system has become complex and diverse, not only at the scale of the ponds, the level of fish intensification, techniques, and technology but also in the integration of other agricultural operations such as livestock and crop cultivation. Because fish production can be integrated within agriculture on current agricultural lands in smallholder and commercial farms, the expansion of freshwater aquaculture in the province has great potential. Therefore, freshwater aquaculture can be assessed to have a key role in food production systems by observing the boom of fish production in the province since its re-establishment in 1997 (Figure 5).[4]

The food production system in Hai Duong evolved significantly over

4 Haiduong was re-established in 1997 from the before province of HaiHung—a merged Hung Yen and Hai Dduong province.

Figure 5. The Area and Production of Freshwater Aquaculture in Hai Duong Province (1997–2014)



Source: Hai Duong Statistical Book, 1999, 2005, 2014.

the last decades. It changed not only in the structure of the food it produces, but also in its production systems, especially for the freshwater production systems. The total production of fish in Hai Duong rose from 9,963 tons to 64,887 tons from 1997 to 2014. There was also a significant increase of aquaculture in the area, from 5,660 (ha) to 10,064 (ha) during the period 1997–2005. The turning point of aquaculture expansion was in 2005 when the Vietnamese government set up a program of food security which prioritized a large area of agricultural lands to maintain rice production (3 million ha) in order to ensure the national food security program. This has clearly impacted the aquaculture expansion in the province. As it was, 70 households (46%) out of the total (151) investigated households started their fish cultures in the period from 1997 to 2005, while only 38% of total households established their fish cultures during the period 1980–1996 (Table 4).

The essential characteristic of IAA systems 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 provides opportunities for more nutrient linkages, and a possibility to meet increased nutrient requirements for enhanced production,

Table 4. The Start-Up Period of Fish Production at Farms in Hai Duong

(Unit: household)

Period	FS system	AF system	VAC system	Total
1980–1996	23	27	8	58
1997–2005	17	31	22	70
2006–2014	11	7	5	23
Total	**51**	**65**	**35**	**151**

Source: survey, 2015.

although this requires additional labor. This opens avenues 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, diversification leads to opportunities for off-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 revealed changes in the household size, paddy land, homestead land, agricultural land, number of fruit trees, and the total head number of animals raised because of their systems (Table 5). Farms with VAC systems had a larger number and area of fruit trees than those of two other systems, but also fewer fish ponds in the area. Additionally, the VAC households' ownership of agricultural land was the smallest; the households with animal/fish production systems are characterized by more reared animals, paddy land, homestead land, and more family members in comparison with those of households belonging to commercially intensive fish production systems. Although the fish pond was the smallest area for the households with the VAC system, the pond plays an important role in effectively utilizing households' production resources and recycling wastes. Fish farming was not considered as a high priority because it was employed by poor households with limited agricultural land and capital investment. The main goal of their farming is to meet their food security and subsistence needs. In contrast, among farmers engaged in animal/fish production and highly commercial fish production, the fish production was the major objective from the outset, rather than the pond being simply a development of the homestead and fruit orchards.

Economic Effectiveness and Efficiency of Freshwater Aquaculture Production Systems

In fact, freshwater aquaculture systems were greatly diversified and intensified. There was increased reliance on plant residue/manure, increased inorganic fertilizer inputs, and use of low-cost feeds. Furthermore, some manure and inorganic fertilizer use requires aeration and closer fish

Table 5. The Characteristics of Fish Farms in Hai Duong Province

	Unit	FS system (N=51)		AF system (N=65)		VAC system (N=35)	
Age	Year	52.1	(9.79)	52.5	(8.35)	55.8	(8.36)
Household size	People	3.02*	(1.09)	3.80*	(1.12)	3.51	(1.40)
Number of laborers	Labor	2.45	(0.92)	2.86	(1.10)	2.66	(1.45)
Agriculture land	Sao(#)	18.7	(9.10)	18.3	(7.76)	11.7*	(3.82)
Homestead land	m^2	353.0*	(271)	512.3*	(430)	459.5	(228)
Paddy land	Sao(#)	4.20*	(3.48)	6.17*	(3.10)	5.20	(3.42)
Area of fruit trees	m^2	230	(371)	317.2	(600)	515.6	(878)
Number of fruit trees	Tree	36*	(56.00)	45	(64.75)	103*	(171.20)
Number of animals raised	Heads of animals	23*	(26.36)	188*	(234.4)	39	(36.01)
Area of aquaculture land	Sao(#)	14.49	(9.58)	12.12	(7.01)	6.51*	(2.46)
Number of owned ponds	Ponds	2.27*	(1.56)	1.88	(0.89)	1.34*	(0.48)
Experience in aquaculture	Year	16.5	(7.23)	17.6*	(7.27)	14.1*	(4.85)

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

Source: survey, 2015.

health management. Often in more intensive aquaculture production systems, there is a change in food management during a production cycle, e.g. from an initial basis of manure and fertilizer inputs, to a gradual shift to pellet feeding as the main input. The freshwater aquaculture system's trends are characterized by product specialization, market/commercial orientation, off-farm or between-farm integration, and de-integration (i.e. reduction in emphasis on recycling flows) and greater emphasis on inorganic fertilizers and fish feeds, compared with a previous reliance on manure or sewage as the main nutrient sources. However, a trend toward diversification of the produced fish into the production of high-value marketable species is emerging in the survey sites.

In Hai Duong, polyculture is applicable mainly for fish production in which the number of species of fish ranges from 2 to 6; carp being the most common species found in stock in the survey households. Fish were normally harvested after 10 months of being stocked. The stocking density was calculated based on the total area for fish production (included bankers/dikes of the pond), so the calculation of the

Table 6. The Status of Fish Production at Farms in Hai Duong Province

	Unit	FS system (N=51)		AF system (N=65)		VAC system (N=35)	
Area of aquaculture	Sao	14.49*	(9.58)	12.12	(7.01)	6.51*	(2.46)
Number of ponds	ponds/ household	2.3*	(1.56)	1.9	(0.89)	1.3*	(0.48)
Production cycle time	Months	9.8	(2.59)	10.5	(1.88)	10.7	(2.03)
Stocking density	fish/m^2	0.81	(0.59)	0.84	(0.62)	0.78	(0.47)
Kinds of fish	Fish/stocking	4.31	(1.22)	4.37	(1.18)	4.31	(1.39)
Production	kg/household	4,727	(4,176)	4,254	(2,475)	2,144	(1,233)
Yield	kg/sao	325	(166)	359	(176)	339	(164)

(*) The mean difference is significant at the 0.05 level.
Calculation of stocking density included pond-dike area. Parentheses are standard deviations.

Source: survey, 2015.

stocking density was less than one in every m^2. The total production ranged from 150 to 17,740 kg/household annually. On average, the largest fish production was concentrated to FS households with 4,727 kg/household, followed up by AF households with 4,254 kg/household, while it was only 2,144 kg/household for VAC households. However, the yield (339 kg/sao) of VAC households is larger than that of the FS households (325 kg/sao). ANOVA tests revealed the significant difference in the number and area of fish ponds between the groups of FS and VAC households (Table 6).

In recent decades, a number of studies on the impact of aquaculture production systems on household nutrition have been conducted in rural areas. The studies reveal that considerable benefits result either from the direct consumption of fish by the producing households or from gains in income, so that fish farms can afford to purchase other cheaper foods, which nevertheless leads to an improved household diet (Ahmed & Lorica, 1999; Prein & Ahmed, 2000; Ruddle & Prein, 1998; Sultana, 2000; Thilsted & Roos, 1999; Thompson, Sultana, Nuruzzaman, & Firoz Khan, 1999). Further direct benefits from rural integrated aquaculture, aside from increased household nutrition and income, are the local availability of fresh fish and the provision of employment for household members. Indirect benefits are the increased availability of fish to local and urban markets which may lead to a reduction in prices; increased employment benefits through the development of an industry providing work on fish farms and in related services; and the development of seed supply networks.

In Table 7, All Purchased Activity Direct Inputs, resources, and benefits associated with the three systems are shown. When calculating the economic benefits, only resources that are tradable in the region were taken into ac-

Table 7. Economic Effectiveness and Efficiency of Fish Production per Sao at Farms in Hai Duong Province

Unit: 1,000 VND

	FS system (N=51)	**AF system (N=65)**	**VAC system (N=35)**
Total value of fish	**13,336.7**	**15,610.2**	**15,100.8**
All variable costs *(Purchased Activity Direct Inputs)*	***6,043.8***	***7,596.4***	***6,700.2***
Fingerlings	2,202.8	2,577.4	2,995.3
Feed	5,480.2	6,821.1	5,655.5
Fertilizer	3.6	1.0	9.4
Lime	92.7	113.2	84.5
Chemicals	242.4	283.6	208.2
Energy	187.6	335.7	338.7
Other	48.6	48.6	28.5
Gross margin of fish	**7,292.9**	**8,013.8**	**8,400.7**
All capital Depreciation*	***775.3***	***1,079.5***	***1,028.0***
Family farm available Income of Fish	**6,517.6**	**6,934.4**	**7,372.7**
Working labor (man-days)	**14.03**	**16.43**	**32.64**

**The fixed cost is calculated based on depreciation over 10 years.*

Source: survey, 2015.

count. The operation of the pond was carried out through family labor; thus, the opportunity costs from the labor of collecting leaves and grasses as feed and manure as fertilizer were not included here, as these resources had no monetary value in the research area. Under the VAC system, cereals (maize and rice), rice bran, and some agricultural by-products were resources with a market value and showed a high variation in the amount used as pond input. Under the farming management of AF and FS systems, compound feed was the highest financial input, comprising on average (90%) of the total value of pond inputs. The variable costs were feed, fertilizer, lime, chemicals, electricity, and other operational costs. Labor is excluded in the price of the total cost. However, labor employment was estimated and research calculations showed that fish farms with the VAC system are the most labor-intensive (32.64 man-day per sao). Chemical, lime, and inorganic fertilizers accounted for 5% of the financial input. The VAC farms' Gross Margin (8.4 mill VND) and Family Farm Available Income (7.4 mill VND) of fish gained much better than those of from AF and FS systems. These results implied that the fish production systems benefited through integration by becoming more effective and better at resource-utilization. The integration of the aquaculture systems would be A-C or V-A-C.

Contribution of Freshwater Aquaculture to the Food System and Rural Development

Taking aquaculture's contribution into account when discussing food systems and rural development, it is, perhaps, not surprising that aquaculture production has grown rapidly since the 1980s and has been the fastest growing food production sector in the survey areas for more than three decades. In 1996, aquaculture production contributed approximately 2.7% and in 2014, 12% of the total gross production of agriculture in the province.

The average gross income of households in which off-farm income was excluded (from 6/2014 to 6/2015) ranged from 10,000,000 VND/year (US$ 500/year) to 333,530,000 VND/year (US$ 15,000/year). This figure for the FS group was 72,136,000 VND/year (US$ 3,200/year), less than that of the AF group, 98,430,000 VND/year (US$ 4,406/year), but higher than those of the VAC group, 53,586,000 VND/year (US$ 2,613/year). However, the difference between the total household income among the groups was not statistically significant. On-farm income includes revenues from various enterprises such as cultivating rice, raising livestock, fish production, growing non-rice crops, and growing fruit trees, which all create an annual cash income for the farmers. Any enterprises that were just for personal consumption or recreation, but not for earnings, were ignored in this study because they do not contribute to the farmers' income. Similar to the results for whole-household income, the Kruskal–Wallis tests did not find any significant differences between the groups in terms of the income of farming enterprises. However, the calculations of the average income from various sources gave a general impression of income differences among the three groups. At the whole-farm level, the AF farmers appeared to obtain the highest returns from their farming, although the difference in terms of gross household income was not significant at the time of the study. This result is consistent with the assumption that aquaculture development aimed to improve the situation of the food and foodstuffs, and the diversity of income sources for poor households in rural communities (Table 8).

IV. Conclusion

Over time, freshwater aquaculture production systems are dynamic and are subject to economic and environmental changes. The development of aquaculture in

Table 8. Sources of On-Farm Income at Fish Farms in Hai Duong Province

	FS system (N=51)	Std	%	AF system (N=65)	Std	%	VAC system (N=35)	Std	%
Rice crop	5,265	*5,127*	64.47	8,171	*5,601*	62.40	6,818	*5,044*	45.98
Vegetable crop			-	1,380	*3,273*	10.54	1,053	*2,348*	7.10
Fruit crops	2,902	*3,333*	35.53	3,544	*3,943*	27.06	6,958	*8,591*	46.92
Total crops	***8,167***	*5,878*	***11.32***	***13,096***	*7,709*	**13.30**	***14,829***	*10,769*	***7.67***
Livestock husbandry	***4,905***	*5,289*	***6.80***	***34,162***	*31,865*	***34.71***	***8,078***	*5,949*	***15.07***
Fish production	***59,064***	*61,354*	***81.88***	***51,172***	*37,103*	***51.99***	***30,681***	*23,659*	***57.26***
Total	**72,136**	*66,758*	**100.00**	**98,430**	*60,928*	**100.00**	**53,586**	*28,927*	**100.00**

Source: survey, 2015.

the Red River Delta has shown the evolution from low-input on-farm integrated systems to high-input off-farm integrated and commercial systems, supplying significant amounts of fish to rural and urban consumers. The aquaculture production systems play a key role in the development and diversity of food systems. This is clear evidence that these fish production systems, especially IAA—VAC and AF systems are becoming more and more important in northern Vietnam for food security and rural development.

The mono-aquaculture or intensive fish farming (FS system) seems to be less efficient and stable in terms of resource-utilization and economic fears (production risks, market risks ...). With similar levels of farm resources, and investment capital, farms with the AF system are able to obtain a much better return than that of farms belonging to the FS system. Moreover, the most efficient farms use the VAC system. This strongly supports VAC as a sustainable food system in developing countries in the context of rapid loss of agricultural land to urbanization and industrialization. What will be the sustainable food production system of the future? Which will feed the growing population on smaller and smaller areas of cultivated land?

Aquaculture integration has considerable potential within the VAC system in the region, which is significant for poor farmers in developing countries where access to farming resources, investment capital, and food security are still problematic. Further research on the system that focuses on economic, environmental resource-utilization, and social benefits will shed light on its contribution to poverty reduction and improvements to livelihoods, as well as food security for most small-scale rural farmers.

Furthermore, poor rural people might also benefit from the provision of low-cost fish. If it is well planned and managed, VAC farming can significantly contribute to the process of the agricultural diversification, the reduction of vulnerability and farm sustainability, and rural development, i.e. diversifying the sources of income, increasing the employment and welfare of rural people, and safeguarding against environmental pollution.

References

Ahmed, M., & Lorica, M. H. (1999). Improving developing country food security through aquaculture development: Socioeconomic and policy issues. Paper presented at World Aquaculture 99, the Annual International Conference and Exposition of the World Aquaculture Society, Sydney, Australia, 26 April–2 May (no published proceedings).

Belton, B., & Little, D. C. (2011). Contemporary visions for small-scale aquaculture. In Chuenpagdee, R. (Ed.) World small-scale fisheries: contemporary visions (pp. 151–170). Delft: Eburon.

Dey, M. M., & Ahmed, M. (2005). Aquaculture—food and livelihoods for the poor in Asia: A brief overview of the issues. Aquaculture Economics & Management, 9, 1–10.

Dey, M. M., Rab, M. A., Paraguas, F. J., Bhatta, R., Alam, M. F., Koeshendrajana, S., & Ahmed, M. (2005). Status and economics of freshwater aquaculture in selected countries of Asia. Aquaculture Economics and Management 9, 11–37.

Edwards, P. (1993). Environmental issues in integrated agriculture-aquaculture and wastewater-fed fish culture systems. In R. S. V. Pullin, H. Rosenthal, & J. L. MacClean (Eds.), Environment and aquaculture in developing countries. ICLARM Conf. Proc. 31, pp. 139–170.

Edwards, P. (2000). Aquaculture, poverty impacts and livelihoods. ODI Nat Resour Perspect 56.

FAO. (2011). Aquaculture production 1950–2009 (data set for Fishstat Plus). FAO Fisheries Department, Fishery Data and Statistics Unit.

FAO. (2013). Food balance sheets. Vietnam. Retrieved September 14, 2015, from http://faostat.fao.org/site/368/DesktopDefault.aspx?PageID=368#ancor

Hai Duong Statistics Office. (1999). Hai

Duong Statistical Yearbook. Ha Noi: Statistical Publishing House.

Hai Duong Statistics Office. (2005). Hai Duong Statistical Yearbook. Ha Noi: Statistical Publishing House.

Hai Duong Statistics Office. (2014). Hai Duong Statistical Yearbook. Ha Noi: Statistical Publishing House.

Hanh, H. Q., Ton, V. D., & Lebailly, P. (2013). Dynamics and constraints of livestock productıon systems in Cam Giang district, Hai Duong Province, North Vietnam. Livestock Research for Rural Development, Volume 25, Article#158. Retrieved June 19, 2017, from http://www.lrrd.org/lrrd25/9/hanh25158.htm).

Lebailly, P., et al. (2015). Développement rural et petite paysannerie en Asie du Sud-Est: Leçons d'expériences au Vietnam et au Cambodge (Rural development and small farmers in South East Asia: Lessons of experiences in Vietnam and Cambodia). France, Paris: L'Harmattan.

Little, D. C., Barman, B. K., Belton, B., Beveridge, M. C., Bush, S. J., Dabaddie, L., ... Morales, E. (2010). Alleviating poverty through aquaculture: progress, opportunities and improvements. In Farming the Waters for People and Food, Proceedings of the Global Conference on Aquaculture Phuket, Thailand. 22-25 September 2010. FAO, Rome and NACA, Bangkok (pp. 22–25).

Luu, L. T. (2001). The VAC system in Northern Vietnam. In Integrated agriculture-aquaculture: A primer, pp. 29–32 (FAO Fisheries Technical Paper 407).

Luu, L. T. (2002). Sustainable aquaculture for poverty alleviation (SAPA): A new rural development strategy for Viet Nam—Part II: Implementation of the SAPA strategy. (FAO Aquaculture Newsletter—December 2001—No. 28).

McConnell, D. J., & Dillon, J. L. (1997). Farm management for Asia: A systems approach. Rome: Food and Agriculture Organization of the United Nations.

Mishra, V., & Ray, R. (2009). Dietary diversity, food security and undernourishment: The Vietnamese evidence. Asian Economic Journal, 23, 225–247.

Misui, H., & Horiuchi, H. (2006). Classification of VAC farming systems: A case study of Bac Son Commune in the Red River Delta, Vietnam. http://agris.fao.org/agris-search/search.do?request_locale=en&recordID=JP2007003025&sourceQuery=&query=&sortField=&sortOrder=&agrovocString=&advQuery=&centerString=&enableField=.

Pekar, F., Be, N. V., Long, D. N., Cong, N. V., Dung, D. T., & Olah, J. (2002). Eco-technological analysis of fish farming households in the Mekong Delta, Vietnam. In P. Edwards, D. C. Little & H. Demaine (Eds.), Rural aquaculture (pp. 77–95). CABI Publishing, UK.

Prein, M. (2002). Integration of aquaculture into crops-animal systems in Asia. Agriculturalsystem, 71, 127–146.

Prein, M., & Ahmed, M. (2000). Integration of aquaculture into smallholder farming systems for improved food security and household nutrition. Food and Nutrition Bulletin, 21(4), 466–471.

Ruddle, K., & Prein, M. (1998). Assessing the potential nutritional and household economic benefits of developing integrated farming systems. In J. A. Mathias, A. T. Charles, & H. Baotong (Eds.), Integrated Fish Farming. Proceedings of a Workshop on Integrated Fish Farming, 11–15 October 1994, Wuxi, Jiangsu Province, China. CRC Press, Boca Raton, FL, pp. 111–121.

Ruddle, K., & Zhong, G. (1988). Integrated agriculture-aquaculture in South China: The dike-pond system of the Zhujiang Delta. Cambridge University Press, UK.

Sultana, P. (2000). Household fish consumption and socio-economic impacts in Kapasia. Paper presented at the Workshop on Aquaculture Extension: Impacts and Sustainability, 11 May 2000, Dhaka, Bangladesh. ICLARM, Penang, Malaysia and the Department of Fisheries, Dhaka, Bangladesh, p. 7.

Tacon, A. G. J. (1997). Contribution to food fish supplied. In Review of the state of world aquaculture. FAO Fisheries circular no. 886, Rome, Italy.

Thilsted, S. H., & Roos, N. (1999). Policy issues on fisheries in relation to food and nutrition security. In M. Ahmed, C. Delgado, S. Sverdrup-Jensen, & R. A. V. Santos (Eds.), Fisheries Policy Research in Developing Countries: Issues, Priorities and Needs. ICLARM Conference Proceedings 60. ICLARM, Penang, Malaysia, pp. 61–69.

Thompson, P., Sultana, P., Nuruzzaman, M., & Firoz Khan, A. K. M. (1999). Fisheries Extension Evaluation Project. Progress Report, March 1998 to Mid-1999. ICLARM, Penang, Malaysia.