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Integrated Agriculture-aquaculture Farming Systems in Vietnam: The Status Quo and Future Perspectives

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Abstract

The integrated agriculture-aquaculture (IAA) farming system has been considered a form of diversified agriculture applied in Asia. In this paper, several IAA farming systems practiced in Vietnam are described, and their impacts are also reviewed. It is speculated that in developing countries like Vietnam, the IAA farming system should be targeted for support as a sustainable food safety model and a form of ecosystem-based technology to reduce environmental impacts, adapt to climate change, help avoid risks from market fluctuation, and increase incomes in comparison with monoculture farming.

Keywords

Agriculture, aquaculture, IAA, farming, Vietnam

Introduction

The integrated agriculture-aquaculture (IAA) farming system has been considered a form of diversified agriculture mainly practiced in most Asian countries, including China, India, Indonesia, Thailand, Vietnam, and Bangladesh (Little & Muir, 1987; Edwards *et al.*, 1988; Pingali, 2012). Prein (2002) defined this system as "concurrent or sequential linkages between two or more human activity systems, one or more of which is aquaculture, directly on-site, or indirectly through off-site needs and opportunities or both". In general, IAA systems consist of three major sub-systems: aquaculture, agriculture, and household activities (Zajdband, 2011). In terms of advantages, IAA systems can reduce the need for external inputs, thus increasing total farm productivity and profitability through increases in resource-use efficiency. As examples, animal manure can be used as pond fertilizer and crop by-products can be used as supplementary feed for aquatic animals, while aquaculture wastewater and sediments can be used for crop irrigation and organic fertilizers, respectively (Zajdband, 2011). However, in terms of disadvantages, IAA systems can enhance disease transmission and

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increase potential public health risks through an increase in the movement of antibiotic-resistant bacteria between terrestrial and aquatic animals (De Silva *et al.*, 2009).

In Vietnam, the diversified farming systems that flourished after the Doi Moi (Renovation) movement were the combination of rice and other commercial products such as fish, terrestrial animals, and fruits (Tanaka, 1995). In the beginning, integrated farming was a traditional approach to family food production in the poor, rural regions of Vietnam. Because of the adoption of the VAC system (VAC in Vietnamese stands for Vuon, Ao, Chuong, which translates to garden, fishpond, and livestock pen), the dietary balance of the rural poor was significantly improved by the addition of dietary protein, particularly in the isolated villages located in the high mountainous areas. Subsequently, for economic purposes, the VAC system gradually developed to be market-oriented for improving the farmers' income, as well as being modified to be suitable for existing infrastructure and natural conditions. Misui and Horiuchi (2006) identified at least 14 types of farming enterprise combinations in the VAC system, such as VAC, VA, VC, AC, VC + rice, AC + rice, and A + rice. In this paper, several IAA systems that are common in Vietnam, such as VAC, fish-livestock, rice-fish/shrimp/prawn, and mangrove-shrimp farming systems, are reviewed to have a better understanding of the diversity of IAA systems in Vietnam.

Integrated Agriculture-Aquaculture Farming Systems in Vietnam

Integrated VAC farming

VAC stands for integrated production systems comprised of three components: (1) horticulture (gardening), (2) aquaculture, and (3) livestock husbandry. In terms of horticulture/gardening, various plants (timber, bamboos, rattans, creepers, fruit trees, vegetables, legumes, and medicinal plants) are cultivated in multilayers in such a way that all the plants can absorb enough solar energy to express good growth and generate high productivity. In terms of aquaculture, one or a few ponds are created either in the center or close to one edge of the garden for multiple uses, such as for aquaculture, serving as a water reservoir, and as a water source for the cultivation of crops. In terms of livestock husbandry, livestock such as buffalos, cows, pigs, chickens, ducks, and rabbits are often reared. Pens or cages are built in places suitable for energy and nutrient recycling within the VAC system. The interactional relationship in the VAC system (**Figure 1**) is briefly described as follows: some products from the garden (V) are used to feed the fish (A). The fishpond (A) is considered as a nutrient trap to provide water, mud, and sediments to irrigate and fertilize the garden (V). Some of the fish can be used as nutritious animal feed (C). Animal manure (C) is used as a nutrient source for plants (V) and as fish feed (A).

The VAC system, therefore, effectively uses all the available land, air, water, and solar energy resources, and effectively recycles by-products and waste. The VAC layouts and the types of plants and animals included can be highly diverse between households and communities. VAC practices lead to increased income and improved standards of living. A survey focusing on the economic potential of VAC systems has shown that for some communes in the Red River Delta where VAC farming is practiced, VAC income constitutes 50 to 70% of the farmers' income, and their annual income through VAC farming is three to ten times higher than that derived from growing two rice crops per year in the same area (VACVINA, 2012; Do Van Hoa *et al*., 2020).

Since 1985, the Vietnamese government has been encouraging the development of family-sized economic units. In 1986, the association of Vietnamese gardeners (VACVINA) was founded, and currently, it has branches in each of Vietnam's 58 provinces. The main objectives of this non-governmental organization are to promote VAC development, provide education, support, and transfer technology to enable farmers to practice VAC, and to exchange information with international organizations.

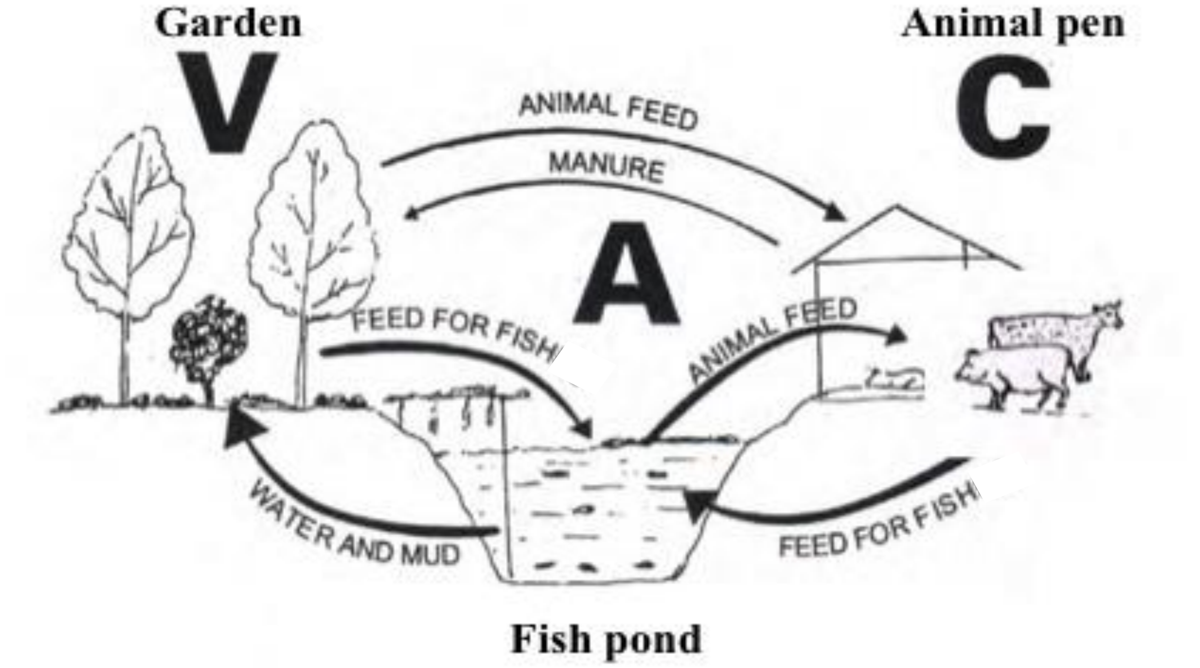

Figure 1. Internal nutrient flows between components in the integrated VAC (Vuon - Ao – Chuong) system in Vietnam
Source: VACVINA (2012)

Integrated fish-livestock farming

Integrated fish-livestock farming is a modified VAC system practiced mainly in rural areas in Vietnam. Livestock animals in this system are mainly ducks, chickens, and pigs, while the fish are mainly traditional fish (common carp (*Cyprinus carpio* Linnaeus, 1758), Chinese carps, Indian major carps), and tilapia (*Oreochromis niloticus* Linnaeus, 1758). In integrated fish-livestock farming, fishponds provide water and food for livestock, while wastes from animal husbandry, such as manure, urine, and surplus feed, are used for fish culture. Livestock manures play a role as pond inputs for the development of natural fish feed such as phytoplankton, zooplankton, benthic organisms, and detritus (Kwei Lin *et al.*, 1997; Knud-Hansen, 1998). Livestock manures are further grouped according to whether they originate from poultry (mainly chickens and ducks), ruminants (cows, buffalo, sheep, and goats), or pigs. Poultry and pig manures are usually of high quality, while ruminant manures have a low carbon to nitrogen ratio and are of less use as a pond input unless balanced with alternative nitrogen sources.

Integrated rice-fish farming

Rice-fish farming is closely integrated with freshwater fish farming in Vietnam. The intentional stocking and culture of fish in rice fields has a long history with numerous designs and experiences in experimentation and implementation. Usually, a small portion (about 5 to 20%) of the area of the rice field is converted into a trench, a refuge pond, or a combination of both. Trench layouts vary considerably in their location in the rice fields. Recently, a different approach has been applied for deep water rice-fish culture in seasonally flooded areas. In the flooding season, the areas are stocked with fish, while in the dry season, the areas revert again to rice cultivation. Fish cultured in this system are mainly traditional fish and tilapia.

The integrated fish-in-paddy field system functions through the feeding of fish on organisms (particularly insects and other possible rice pests) and weeds, and the stirring of the sediment through their foraging actions, which leads to nutrient resuspension (Lightfoot *et al.*, 1993; Cagauan, 1995). The benefits of rice-fish culture as a low-investment and entry-level technology system for resource-poor farmers have been demonstrated in Vietnam (Rothuis, 1998).

Phong *et al*. (2011a) evaluated the environmental impacts of IAA farming in the Mekong Delta region of Vietnam among three different systems: a rice-based and high input fish system (R-HF), a rice-based and medium input fish system (R-MF), and an orchard-based and low input fish system (O-LF). The study showed that the global warming potential, energy use, and eutrophication potential per kcal of farm product tended to be higher, and acidification potential was higher, in O-LF than in R-HF and R-MF. The impact per kg of pig and poultry protein was on average 1.6-1.8 times higher than the impacts per kg of fish protein. In addition, excessive and inefficient uses of fertilizers, and CH_4 emissions from the paddy fields contributed the most to the environmental impact in rice production (Phong *et al*., 2011a).

Integrated rice-shrimp/prawn farming

Integrated rice-shrimp/prawn farming has recently become more popular in Vietnam, especially in the Mekong Delta. This kind of integrated system has been considered as a potential model to deal with the impacts of climate change. According to the Directorate of Fisheries, the potential area suitable for rice-shrimp/prawn culture in the Mekong Delta is about 250,000ha. It was estimated that about 160,000ha were dedicated to the rice-shrimp/prawn system in 2015, in which the production of shrimp/prawn was about 300 to 500 kg ha^{-1} (Hai Linh, 2020).

There are two types of integrated rice-shrimp/prawn farming systems. The first system includes a crop of shrimp and a crop of rice, while the second system includes a crop of shrimp and a crop of integrated rice and prawn. The shrimp cultured in this system are mainly black tiger shrimp (*Penaeus monodon* Fabricius, 1798), while the cultured prawn is the giant freshwater prawn (*Macrobrachium rosenbergii* De Man, 1879).

Integrated mangrove-shrimp farming

In Vietnam, integrated mangrove-shrimp farming is well suited to coastal provinces that have mangrove forests, such as Ca Mau Province. Shrimp cultured in this system are mainly *P. monodon*.

Recently, the Mangroves & Markets (MAM) Project, sponsored by BMUB (German Ministry of Environment, Natural Resources, Building, and Nuclear Safety), was implemented in Vietnam. The main objectives of the MAM project are to restore the mangrove forests and to promote the culture of organic shrimp (Naturland certification). Under the MAM project, integrated mangrove-shrimp farming requires a mangrove forest covering of at least 50% on shrimp farms. About 15,000ha of shrimp-mangrove farming belonging to 3,000 households were established in Ca Mau Province in 2015. Since the conclusion of the MAM final workshop, which was held in Ho Chi Minh City in 2016, the SNV Netherlands Development Organization has been working with BMUB and partners on the next phase of the project, which will scale up this integrated mangrove-shrimp model across the Mekong Delta, including provinces such as Ben Tre and Tra Vinh (IUCN, 2018). This integrated mangrove-shrimp farming system produces organic shrimp that are resistant to diseases because of the regular tidal flows, is economically attractive, and has the potential to play a key role in coastal climate change adaptation.

Integrated shrimp-tilapia farming

Integrated shrimp-tilapia farming has recently been applied in Vietnam because it is believed that this system can prevent or minimize shrimp diseases in general and acute hepatopancreatic necrosis disease (AHPND) in particular (Tiasang, 2015). There are four kinds of integrated shrimp-tilapia farming systems practiced in Vietnam: (1) culture of tilapia directly in shrimp ponds: tilapias are stocked at a density of 1 fish m^{-2}, while shrimp are stocked at a density of 20 to 40 shrimp m^{-2}; (2) culture of tilapia in cages/nets which are located in shrimp ponds: tilapia are stocked at a density of 10 fish m^{-3}; the area of cage/net is about 2% of the shrimp pond area; (3) culture of tilapia in ponds/tanks that will supply water for shrimp ponds: tilapia are stocked at a density of 4 to 5 fish m^{-2} and are not fed; and (4) shrimp crop is rotational with tilapia crop.

Impacts of IAA Farming systems in Vietnam

Positive impacts

Haylor (2003) pointed out that the characteristics of suitable IAA technologies are that the systems should be of low risk to farmers, require low investment, provide quick returns, be simple and easily replicated, provide the capability to establish local fish supply capacity, and be easily taught to trainers and farmers. The direct benefits from the IAA farming systems, aside from increased household nutrition and income, are local availability of fresh fish and the provision of employment for household members. Indirect benefits include the increased availability of fish to local and urban markets that may lead to a reduction in prices, and increased employment through the development of an industry providing work on fish farms and in related services (Edwards, 2000).

It is believed that the integrated VAC system was originally used as a technology for poverty alleviation in Vietnam. The integrated VAC system was later encouraged for several additional reasons. Firstly, it increases the income of household-scale farms with little capital input. Secondly, it reduces the economic risks involved in the rice monoculture system, which is vulnerable to price fluctuations in the international rice market. Thirdly, it is ecologically desirable since it utilizes various ecological niches within the farm, thus leading to sustainable land use in comparison with monoculture systems, which often necessitate extensive environmental transformation. Similar advantages have been observed in other IAA farming systems, such as fish-livestock farming, rice-fish farming, and rice-shrimp/prawn farming (de la Cruz *et al.*, 1992).

Integrated mangrove-shrimp farming has been considered as a form of ecosystem-based adaptation in which the mangrove ecosystem contributes to climate change mitigation. Mangrove ecosystems provide a natural habitat for shrimp, require no feed, chemicals, or antibiotics, and result in reduced diseases. Also, integrated mangrove-shrimp farming produces organic shrimp at better prices.

Phong *et al*. (2010) evaluated the ecological sustainability of IAA systems among the R-HF, R-MF, and O-LF farming systems in the Mekong Delta region of Vietnam. The data analysis showed that the variability in ecological sustainability among farms was high, caused by differences in land use, financial situations, disease constraints, market demand, and family conditions. The R-HF system scored higher on productivity-efficiency while fertilizers were usually applied in excess in the O-LF system (Phong *et al*., 2010).

Integrated shrimp-tilapia farming has been suggested as an alternative approach for shrimp farming, which could ultimately lead to a more sustainable shrimp industry. This system could improve water quality in shrimp ponds, reduce disease, and reduce the use of chemicals and antibiotics (Yi & Fitzsimmons, 2004).

Negative impacts

Some potential risks can be found in the IAA farming systems. Firstly, pesticides used for cultivation activities may remain in crop products and land, which could impact animals and aquaculture species. Secondly, animal wastes (manure, urine, surplus feed) containing antimicrobial residues and resistant bacteria will be discharged directly into fishponds. Also, antimicrobial residues and resistant bacteria from fishponds may be transferred to animals through water. Thirdly, cross-contamination in IAA farming may increase levels of bacterial antimicrobial resistance (AMR), which may impact human health via the food chain.

Soil nutrient balances can be used as an indicator to determine nutrient use efficiency of farming systems (Stoorvogel, 2007; Cobo *et al*., 2010). Phong *et al*. (2011b) monitored soil nutrient balances in three IAA systems in the Mekong Delta: R-HF, R-MF, and O-LF. The results showed that nitrogen, phosphorus, and potassium surpluses were observed in all three systems. In addition, the O-LF system had the smallest nitrogen surplus while the R-HF system had the smallest surpluses of phosphorus and potassium. These data indicated that soil fertility will be maintained in IAA farming systems although there is a risk for environmental contamination (Phong *et al*., 2011b).

Livestock, mainly chickens and pigs, are often fed feed containing growth promoters. Petersen *et al.* (2002) reported that these growth promoters in animal husbandry have been linked to certain AMR patterns among human bacterial pathogens, suggesting that there is a possible flow of AMR genes between animal and human pathogens. The potential transfer of resistant bacteria and resistant genes from aquaculture environments to humans may occur through direct consumption of antimicrobial-resistant bacteria present in fish and associated products (Petersen *et al.*, 2002). Oxytetracycline-resistant *Acinetobacter* spp. isolates have been found from integrated fish farms in Thailand (Agerso & Petersen, 2007). Similarly, the development of antimicrobial-resistant bacteria has been found in integrated fish-livestock farming in Vietnam (Dang *et al.*, 2011), indicating that potential risks of AMR exist in IAA farming systems.

Challenges and Future Perspectives of IAA Systems in Vietnam

IAA systems are a better strategy for on-farm waste management for farmers in general and especially for smallholder farmers in rural and peri-urban areas, where resources are limited. IAA systems have several advantages, including the improvement of on-farm resource use, increased farming income, environment safeguards, and improved nutrition for families. Thus, IAA systems have been successful in Asian countries such as Vietnam and continue to show the benefits of their application.

However, in the context of rapid agricultural land acquisition due to urbanization and industrialization, and the impacts of climate change causing drought and salinization in many areas in Vietnam, especially in isolated, remote areas and the Mekong River delta, suitable areas for application of IAA systems will be reduced in the future. Moreover, food safety issues nowadays have attracted more attention, and many people prefer eating products with high quality.

Regarding the trends in the development of IAA systems, Phong *et al*. (2008) conducted two surveys in the Mekong Delta region of Vietnam in which several factors, such as land-use intensity, farm diversity, farm inputs, market demand, household income, and natural disasters, were analyzed. The data analysis showed that market demand and natural disasters (e.g. disease outbreaks) were the two main drivers of the trend changes of IAA systems. The IAA systems are demonstrating the trend of moving away from specialization with extensive farming and moving towards diversification and intensification. Well-off farmers with good farming skills and enough capital tended to specialize and intensify their farming practices, while the poorer farmers tended towards diversification in order to safeguard their livelihood and avoid risks (Phong *et al*., 2008).

In summary, IAA systems need to migrate to the diversification of resources and activities for producing simultaneously high-quality products at affordable costs. This justifies the relevancy of IAA but at the same time, one might consider the risk that IAA farmers would abandon their complex systems and turn towards specialized but less sustainable production systems because of the lure of increased incomes from the higher prices of high-quality products. Also, in the context of environmental protection, IAA systems in the future should consider the integration of aquaculture and irrigated farming systems to optimize economic benefits, sustainably use existing energy, resources, and infrastructure, and help protect the environment.

Conclusions

IAA farming systems have contributed to progress towards the sustainable development of agriculture in Vietnam. It is speculated that in developing countries like Vietnam, IAA farming systems should be targeted to support a sustainable food safety model as a form of ecosystem-based technology that could potentially reduce environmental impacts, adapt to climate change, and increase incomes in comparison with monoculture farming.

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