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Article

Dynamics of Farming Systems under the Context of Coastal Zone Development: The Case of Xuan Thuy National Park, Vietnam

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Received: 20 May 2019; Accepted: 27 June 2019; Published: 1 July 2019

Abstract: The study was conducted in Xuan Thuy National Park to provide a comparative assessment of different farming systems under the context of the coastal zone development of Vietnam. Based on a sample of 234 farmers in this area, SCP (Structure–Conduct–Performance) analysis revealed three farming systems: integrated aquaculture–mangrove (IAM), intensive shrimp (ISH), and rice-based (RB) farming. The evaluation of farm performance among the systems indicated that ISH incurred the highest values of variable cost and sustainable family income. Meanwhile, IAM obtained the lowest production cost due to the availability of allocated natural resources. The imbalance of applying synthesized fertilizers and an overdependence on nitro-based fertilizers were reported in the case of RB systems. In comparison with the other coastal areas of Vietnam, these farming systems achieved a lower level of production efficiency. It is urgent for policy makers to take action to promote sustainable farming practices in accordance with the stringent enforcement of environmental standards to reduce potential impacts and strengthen the coexistence of systems. Additionally, the purpose of securing rural livelihood under coastal development is aligned with the recommended solutions for economic improvement in this study.

Keywords: dynamics of farming systems; coastal zone; intensive shrimp; integrated aquaculture-mangrove; rice-based; Xuan Thuy National Park; Vietnam

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1. Introduction

Coastal areas offer very favorable environmental conditions for agricultural production (crop, livestock, forestry, and fisheries) due to fertile soil and a substantial supply of water. Higher productivity contributes to improve livelihoods from agriculture and a more sustainable use of fisheries and wetlands. Sustainable yields can increase land availability for other sectors and reduce the clearing and drainage of wetlands. Appropriate agricultural development may increase demand for agricultural inputs, services, and product consumption, which contribute to stimulating the local economy [1]. On the other hand, farming activities create many adverse impacts on the environment of coastal areas. Mangroves and swamp are encroached for cultivation land, resulting in habitat loss and the degradation of biodiversity. The application of fertilizers, pesticides, and agricultural effluent disposal lead to a higher risk of water pollution and lower fish yield, as reported in many coastal zones [1–4]. With spatial proximity to the coastline, agricultural production must include objectives regarding the improvement of farm productivity through environmentally friendly practices, the encouragement of advisory services and appropriate policies, and the maintenance of water flows as well as quality to support coastal resources [1,2,5–7].

With over 3200 km of coastline, the agricultural production of Vietnam is currently based mainly on three distinct systems including shrimp aquaculture, rice-based cropping, and fisheries [8]. Shrimp production has been encouraged by the government to raise income for culturists through increasing trading opportunities and employment in aquaculture production (seed supply, processing, and marketing). The culturing of shrimp in the coastal provinces in Vietnam is classified into four subsystems based on the level of technology applied, stocking density, and yield including extensive, improved–extensive, semi-intensive, intensive, and integrated [8,9]. Extensive is a traditional method that is based mainly on natural recruiting post-larvae from wild sources within ecosystems and obtaining less than 200 kg/ha/year. Semi-intensive involves some stocking of shrimp larvae from a hatchery; its natural productivity is enhanced (1000–2500 kg/ha/year) by some use of feeds and fertilizers. The intensive system relies on high stocking density with a heavy feeding rate and the application of aeration with a yield of 5000–7500 kg/ha/year [8]. Between 2000–2006, semi-intensive and intensive systems were quickly expanded from 0.36 million ha to 0.7 million ha in almost exclusively the coastal provinces [9]. In integrated systems, shrimp larvae and other marine life are managed in mangrove forests along coastlines, and the shrimp yield reaches 200–300 kg/ha/year [9]. However, the development of shrimp production has caused environmental pollution, depleted water supplies, and created disease problems in many southern coastal provinces such as Soctrang, Baclieu, and Camau [8–11], as well as reduced the mangrove forest in northern coastal areas [12–14]. On the social–economic front, shrimp systems in Vietnam are considered as having the potential for improving profitability, increasing trading opportunity, and producing more shrimp products, but there is a high level of risk and indebtedness [11].

Along with the aquaculture sector, there is the diversification of cropping systems of rice and other plants in the coastlines of Vietnam. The double rice cropping of He Thu (summer–autumn) and Dong Xuan (winter–spring) have been practiced since the 1970s. Then, one crop of soybeans was transplantedin1988. He Thu rice is intercropped with second soybean cropping. Farmers grow fruit trees such as orange and sugar cane within rice fields in ditches and dikes. The mixed farming of rice and freshwater fish or shrimp has been also cultivated since the 1990s. The ditches surrounding a paddy field are used for raising fish such as tilapia, carp, or shrimp [15]. The intensification of rice system involves a relatively low risk, less debt, and higher labor wages, but low income for farmers and an increased in use of agrochemicals [11].

Different farming systems have interrelations with each other. For long-term development, one system should perform linkages with others without damaging the ecology [16]. As a research conducted earlier by Gowing and Tuong [8], the unregulated production of shrimp aquaculture and agriculture in the southern coastal zone of Vietnam creates friction between the farmers who derive their livelihoods from shrimp farming and those who depend on rice systems. The occurrence of conflicts between shrimp farmers, rice farmers, and local people whose livelihood maybe adversely affected by environmental impacts refer unsustainable perspectives for coastal areas [8].

Xuan Thuy National Park (XTNP) is a largest coastal wetland in northern Vietnam that has three stages of ecological succession: (1) rice encroaches on sedge (*cyperaceae*) and mangrove (1960–1985); (2) shrimp aquaculture encroaches on mangrove forest (1985–1995); and (3) mangrove forest encroaches on the sea (1995–present) [17]. XTNP has a heterogeneity of farming systems with their evolution. Aquaculture land expands rapidly from 132 ha (1986) to 1561 ha (2013), while rice is the main nutrient source for all households, but slightly decreased from 2346 ha to 2232 ha during the above period [17]. Diverse systems enhance diverse food production, but at the same time, there have been severe problems of development with uncontrolled policies. The depletion of water quality, mangrove fragmentation, and increasing vulnerable levels are challenges that have been recognized by many researchers [13,17–23]. As opined by many agricultural experts, analyzing the existing farming systems corresponding with social, economic, and biophysical parameters is an effective method for proposing activities to protect the soil and water and enhance food security, as well as secure other benefits for farm families [24–28]. Understanding farming systems can contribute to creating appropriate interventions that involve social–economic and management technologies for each system. Currently, empirical information on manifold systems and the interrelations between them in this conservation site has been scant. Agricultural policy makers face a shortage of information for the evaluation of existing agricultural production with government targets. The present study focuses on predominant farming systems that generate main sources of income for locals living in the buffer zone. Currently, there are no people living in the core zone.

In the light of the above, the main aim of this research is to provide a comparative assessment of different farming systems in XTNP under the context of coastal zone development. Moreover, the research at hand has several specific objectives, including (1) describing existing farming systems and management practices, and (2) assessing farm performance and the interrelations between farming systems. The delineation of manifold farming systems is important to inform practical interventions and enhance economic viability as well as the coexistence of the systems in the area.

2. Materials and Methods

2.1. Conceptual Framework

This research adopts the holistic SCP (Structure–Conduct–Performance) to explain the dynamics within farming systems and their characteristics in the study area. The SCP concept was the first introduced by Mason [29]; then, it was used by Bain [30] to account for inter-industry differences in profitability. Recently, many authors applied the SCP paradigm to analyze the agricultural marketing market, and several authors have used it for agricultural production analysis [31–33]. A structure (S) is a set of variables that are relatively stable over time and affect the behavior of farmers and/or buyers [34]. Banson [33] considered the diversification of agricultural production, farmer's associations, access to land, farm size, access to market, and barriers of entry and exit to be components of agricultural structures in Ghana. According to Hampel-Milagrosa [35], the number and size of farms and farmers, the geographical distribution of production, land ownership, tenure, and quality, and the quantity of infrastructure support are components of vegetable production in Philippine. Meanwhile, Gali and Tate [31] stated that the number of producers and buyers, the number of products, the cost structure, diversification and product differentiation, the concentration ratio, and barriers to entry and exit belonged to the structure of the agriculture sector. Structure affects conduct (C). Conduct is the way in which buyers behave, both amongst themselves, and amongst each other [33]. Gali and Tate [31] considered production, promotion, and distribution activities as well as investment and pricing behavior as belonging to conduct. Banson [33] added market analysis, resistance to change, research, and the innovation of producers to the C. Marketing activities were also listed in the C of vegetable production by [35]. Conduct affects performance (P). Performance is the result of the agriculture production in efficiency terms and different profitability levels [34]. P includes revenue, economic growth, employment generation, accessibility [33], productivity [31], quantities, and income [35].

The farming system is a resource management strategy that attempts to achieve economic feasibility and sustained agricultural production in order to meet the diverse requirements of farm livelihoods while preserving the resource base and maintaining a high level of environmental quality [36]. The farming system is defined as a decision-making unit comprising the farm household, cropping systems, and livestock systems, which transforms land, external inputs (seed, pesticides, nutrients, etc.), and labor (including knowledge) into useful products that can be consumed or sold [37]. The farming system comprises subsystems (lower-level systems or components) of cropping systems, the animal raising systems (dairying, piggery, fishery) and the farm households [37]. The farm household is the center of consumption, resource allocation, management, and labor, and can contain more or fewer autonomous subsystems. Rana [38] stated that a farming system consists of different enterprises such as crops, livestock, aquaculture, and agro-forestry subsystems. Each subsystem has Inputs–Process–Outputs that depend on the type of farming (commercial or subsistence) and amount of inputs, process, and outputs [37]. A system consists of boundaries, components, and the interactions between components, inputs, and outputs [38]. In this paper, we conduct SCP analysis to assess diverse farming systems in XTNP under the context of coastal zone development according to the schema outlined in the Figure 1 as below:

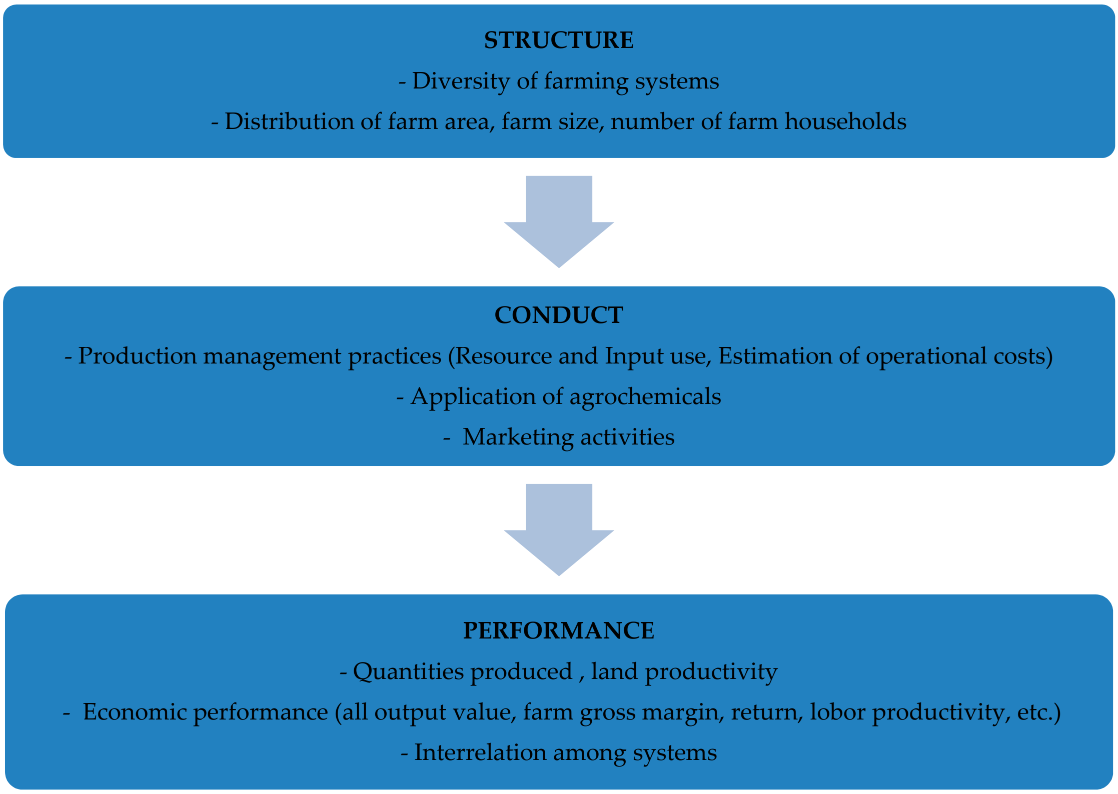


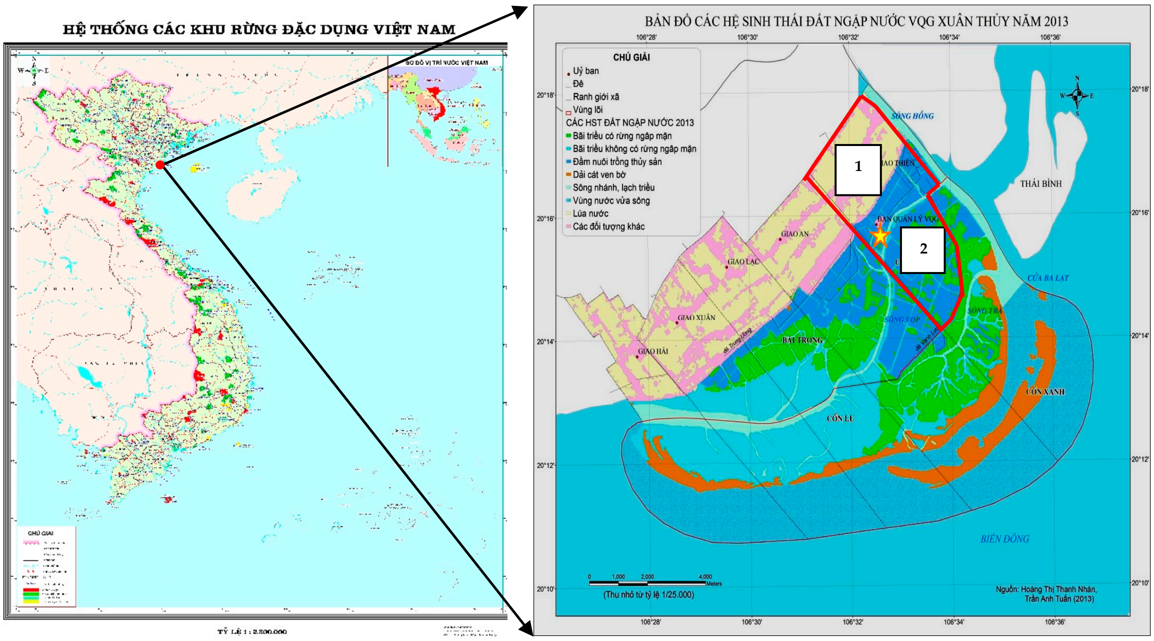
Figure 1. SCP (Structure–Conduct–Performance) framework for farming system analysis.

The elements chosen in our framework are indicators for sustainable agriculture that are required for integrated coastal area management, including: farm characteristics [39], the use of agrochemical and veterinary medicine [40–43], marketing activities and economic performance [43–45], products and productivity [46], and linkages between systems [16]. Moreover, the empirical study in Hoabinh, Vietnam illustrates causal relationships between natural characteristics of farms (area, location), farming practices (use of chemical pesticides, fertilizers, market access, etc.) and farm performance (yield, net farm income) [47].

2.2. *Xuan Thuy National Park*

The study was conducted in XTNP, which is a Ramsar site with international importance as shown in the Figure 2. The protected area extends from 20°10′ to 20°15′ North latitude and 106°20′ to 106°32′ East longitude [48] in Giaothuy district, Namdinh province. It is located on the Balat estuary of the Red River Delta. XTNP covers a total area of 15,100 hectares compromised of a core zone (7100 ha) and buffer zone (8000 ha) [48]. For management purposes, the objectives of the core zone are approved by the Vietnamese Prime Minister as ecosystem conservation, environmental education, ecotourism development, and scientific research. The Department of Agriculture and Rural Development (DARD) of Namdinh province manages a buffer zone with two prior objectives, including environment protection for both the core and buffer zones and the livelihood development of inhabitants.

The park is a typical wetland ecosystem of international and national importance. Internationally, the area is a garden for about 40,000 migratory birds yearly. For Vietnam, it brings great potential for natural resources providing food, creating environment and nursery for aquatic habitats. Moreover, XTNP contributes to shoreline protection and erosion prevention. The park supports a rich biodiversity. The fauna is the home of nine species of mammals, 215 species of birds, 28 species of reptiles and amphibians, 107 species of fish, and 138 species of benthos. The flora has 16 species of vascular plants, 14 species of timber, and six species of mangrove trees. These species mainly grow in Ngan islet and Lu islet [48].



(**a**) (**b**)

Figure 2. Description of the study site. (**a**) Map of protected areas in Vietnam; (**b**) The yellow area is surveyed rice farms (Number 1); the blue area is surveyed aquaculture farms (Number 2); the green area is mangrove trees; the yellow star signifies the XTNP (Xuan Thuy National Park) management board office.

Overall, XTNP has six ecosystem typologies, including tidal wetland with mangroves (1661 ha), tidal wetland without mangroves (2356 ha), aquaculture farming (1699 ha), rice farming (2232 ha), sandy coastal line (989 ha), tidal rivers (950 ha), and estuary (950 ha) [17]. There are 48,000 inhabitants in 12,000 households living in the communal buffer zone, of which 23,000 people are of working age [48]. Rice monoculture covers 85.7% the buffer zone [49]. Rice and aquaculture have become increasingly vital income sources for rural development. They sustain 39.3% and 36% of residents' annual incomes, respectively [48].

The park has five buffer communes (Giaothien, Giaoan, Giaolac, Giaoxuan, and, Giaohai). Among these communes, agricultural production in Giaothien has various ecological typologies, including the largest mangrove wetland combined with shrimp raising (816 ha). Giaothien has unique intensive shrimp aquaculture (150.37 ha) among five communes. Rice production is the primary industry of the locals. Moreover, farms in Giaothien are closest to the Balat estuary and Red river compared with those in other communes. Due to outstanding characteristics, agricultural production in Giaothien is the target for this study, but the farm owners are from both buffer communes and outsiders.

2.3. Data Source and Sampling

Data for this research were collected in two phases. The prior in-depth interviews were conducted in 2017 to classify existing farming systems under administrative management of the Giaothien communal buffer zone. The interviews were conducted with managers of the communal people's committee (CPC), leaders of the communal agricultural board (CAB) and communal agricultural cooperative (CAC), managers of the XTNP board management, and officials of Giaothuy district DARD. In 2018, the number of surveyed households belonging to each system was calculated through the Toro Yamane equation [50]:

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

where n = sample size; N = total households in each system; and e = level of precision. For these parameters, n_1 = 84 integrated aquaculture–mangrove, n_2 = 54 intensive shrimp, and n_3 = 96 rice households. After calculation of the sample size, Fish Bowl Draw sampling was used to choose the respondents in each group. A total of 234 farm households among three farming systems were interviewed to capture detailed information about activity calendars, methods of production, and receipts such as total production, profit, and constraints.

2.4. Data Analysis

The classification of farming systems was based on agricultural and aquaculture focus. Then, some criteria were set up such as natural resources, production mean, farm outputs, etc. For aquaculture systems, we used a diversity of specific criteria to divide systems into specialized or diversified production, stocking density, farm size, input uses, and yield. For agricultural focus, we used criteria of monoculture and mixed crop to classify the cropping systems. This analysis employed qualitative methods rather than statistical techniques.

Then, the economic performance of farming systems was estimated. This emphasis on indicators and measures for annual whole-farm performance were adapted to McConnell and Dillon [51]. Farm economic performances were calculated in following areas: all agricultural outputs/returns (A); variable cost (B) (except family labor); farm fixed cost (C) (except depreciation); depreciation (D); farm gross margin (E = A − B); farm net actual returns (F = E − C); farm net sustainable return (G = F − D); sustainable family income (I = G); working hours of family labor (K); sustainable family income per family labor hours (M = I/K); and external input dependency = purchased input cost/total cost (EID = B/(B + C + D).

Data analysis was carried out with the aid of the statistical package of social sciences (SPSS) computer program version 22.0. The variation in response among the different groups was investigated by Kruskal–Wallis [52] to test the differences of economic indicators.

3. Results and Discussion

3.1. Structure

Three main farming systems in the coastal Ngan islet, which is currently under the administrative management of Giaothien communal buffer zone, were identified according to different production activities and farm performances, as shown in the Table 1.

Table 1. Distribution of land and owners according to different systems in the study area.

Farming Systems	Production Systems	Total Area	Total Farm Owners	No. of Respondents
Integrated aquaculture–mangrove	Shrimp–Crab–Mangrove	816.2	102	84
Intensive shrimp	Shrimp–Shrimp–Fallow	150.37	64	54
Rice-based	Rice–Rice–Fallow	382.0	2737	96
Total		1348.2	2903	234

Source: Household survey, 2017–2018.

3.1.1. Integrated Aquaculture–Mangrove (IAM) System

The Integrated Aquaculture–Mangrove (IAM) system typically uses versions of traditional methods of low-density and low-input systems. Some culturists in the XTNP area started applying the polyculture system in 1986, which is similar with the integrated system in the Mekong delta of Vietnam investigated by Minh and Yakupitiyage [53]. Post-larvae (PL) of black tiger shrimp (*penaeus monodon*) were reared at a stocking density of 5.47 PL/m^2. Crabs are stocked together with shrimps in the ponds. Beside larvae shrimps and crabs, co-products such as wild-catch shrimps (*metapenaeus ensis*), fishes, and seaweed coexist in mangrove farms, and are then harvested as well. This system relies mainly on ephemera going from the Balat estuary, but occasionally, some bivalves and miscellaneous fish are used to enhance the growth of the marine habitats. Farm managers do not adopt chemical fertilizers in their farms. The majority of farm labor comes from individual owner–operators, and only a few laborers are tenants of large farms (about 10 ha). The eight-month production cycle lasts from April to November annually; for the remaining time (December to March), farmers leave the land dry for two weeks. Then, water control gates are opened for an intake of brackishwater with some wild marines (milkfish, wild-catch shrimps) based on tidal regime (about seven times per month). Farmers mainly built ponds adjacent to the Red river and coastal Namdinh based on tidal regime. Rearing ponds with an irregular shape according to land boundaries are generally large areas (an average of 6.82 ha). Currently, farmers mainly purchase black tiger shrimp larvae from hatcheries in five buffer communes of XTNP or in Bentre and Nhatrang provinces of Vietnam. However, farm managers buy crab larvae from all the crab exploiters in the XTNP wetland area. Mangroves (*sonneratia caseolaris, aegiceras corniculatum*) are maintained in farms for providing shelter and the food of aquatic habitats. Farmers dig some ditches through machines with an average depth of 2 m inside farms to prevent hot temperatures in the summer. Shrimps and crabs are harvested prior during July and August after at least 3.5 months from the PL releasing point in April; then, natural fishes, wild-catch shrimps and seaweed are continuously collected until November. All the products are harvested by draining ponds at low tide through a bag net installed in the outlet sluice gate. The size of harvested black tiger shrimps is about 40 heads/kg.

3.1.2. Intensive Shrimp (ISH) System

Intensive Shrimp (ISH) have been farmed in XTNP since 2014. Shrimp culturists have preferences only for monoculture with two raising cycles per year. The first cycle usually starts with pond preparation in March and harvest in June, with an average growth period of around 80–90 days. The second cycle lasts from the end of July to November with more rain than in the winter time and a longer growth duration (100–105 days). ISH ponds are commonly located near rivers (Vop and Tra) or the Balat river mouth with average size of 1.6 ha. White leg prawns (*Litopenaeus vannamei or Penaeus vannamei*) were harvested with a high stocking rate of fries (79.58 PL/m^2/1st crop and 74.40 PL/m^2/2nd crop). Each pond size was 1440 m^2 on average, and built by a mixture of cement and sand, and then covered by nylon. Ponds are drained and dried before stocking. This system depends highly on aeration to circulate water for oxygen for shrimps and phytoplankton. The system requires diverse kinds of inputs to maintain conditions for shrimps including pellet, minerals, and vitamins, and some probiotic or antibiotics. The feed conversion ratio was 1.17:1. The size of harvested shrimps was about 80heads/kg. Shrimps are simply harvested with large scoop nets. After the second crop, farmer clean ponds and leave them fallow for three months from December to February.

3.1.3. Rice-Based (RB) System

The small-scale Rice-Based (RB) cropping system has been cultivated largely by almost all of the households in the coastal buffer zone of XTNP since 1960s [17]. The production system has similar characteristics with the monocultural rice-based agrarian systems that were used between 1980–1985 in Haiduong, which is a province in North Vietnam described by Hanh, Azadi [54]. The cultivation of rice in the conservation area followed the instructions of Giaothuy DARD, which are no different from the other communes in the district. Presently, farmers grow rice in two monocrops per year on the same land. The winter–spring crop starts from the middle to the end of January, when farmers sow or transplant, and then harvest at the end of May. Farmer leave the soil dry for about two weeks before starting the second production crop (summer–autumn) in the middle of June and harvest around the end of October. Most (75%) respondents burn rice straw after harvesting. After the second crop, cultivators dry and fallow land for about eight weeks, and then start preparing land with plough by machines for the next crop. The majority of varieties cultivated are pureline (e.g., BC, Bacthom No.7, TBR225, DQ11, Huongbien No.3) compared to high-yielding rice varieties (e.g.,Tapgiao, Nhiuu 838, TX111, CT16, GS9) due to them being tastier as food. RB requires only low-intensive technological application. Machines are used for the plough and harvest stages of production. Diverse kinds of inorganic fertilizers are applied broadly in paddy fields, while very few numbers of households still use organic compost.

3.2. Conduct

3.2.1. Resource Management

The Table 2 demonstrates land area and its characteristics. IAM culturists in the XTNP buffer zone own farms with an average size of 6.82 ha, in which about 24.28% of mangrove trees are maintained, as self-reported by respondents. These farms are situated closely to the Balat estuary and Namdinh coast. Before 1995, the land—prior to becoming farms—was wetland with dense mangroves and sedge. Since the 1980s, the government allowed residents to cut trees and build farms for raising shrimps and crabs with 70% of farmers having land tenure.

Table 2. Land area and its characteristics.

	IAM	ISH	RB
1. Land holding/owner (ha)	6.82	1.60	0.18
- in which, % mangrove	24.78	0.00	0.00
2. Land prior	Mangrove and sedge	Aquaculture-rice	Rice
3. Land fee (mil.VND/ha/year)	0.00	1.5–6	0.5
4. Ecosystem fee	0.00	0.00	0.00
5. Water source	Sea flow to Vop, Tra and other rivers	Sea flows to Vop and Tra river	Fresh water
6. Water exchange (times/crop)	Tidal regime (48)	7.2	30
7. Distance from farms to agricultural sluice gates (m)	3050.60	1943.52	1020.21

IAM: Integrated Aquaculture–Mangrove; ISH: Intensive Shrimp; RB: Rice-Based; Exchange rate: 1 USD = 23,240 Vietnam Dong (VND). Source: Household survey, 2017–2018.

ISH culturists own smaller farms that are an average of 1.6 hectares, in which pond surfaces account for 60%, and the remaining area included water ponds, drainage areas, and tents or warehouses. Prior to becoming ISH farms, the land was aquaculture-rice because, since 2014, the People's Committee of Giaothuy district issued decision number 4803/QD-UBND to change 150.37 ha of aquaculture–rice farming systems to ISH systems. Currently, 100% of ISH farmers hold land tenures. Rice is cultivated in the area with average size of 0.18 ha per household. Since 2016, the state government has exempted IAM farmers from land taxes. This group can use land without any charges. However, the government is still imposing land fees for ISH and RB. Most of the ISH farmers paid a high rate; especially, the new rate that has been imposed since 2016 (from 1.5–6.0 mil. VND/ha depends on contracts with the communes or districts). Three production systems do not cover the cost of the ecosystem services.

3.2.2. Cost Management

As revealed in the Table 3, the total cost of ISH was the highest, followed by RB and IAM, respectively. It also indicates the heavy dependence on artificial inputs in the case of RB (97.61%) and ISH (92.03%), whereas IAM tended to rely more on environmental supports (70.99%).

Table 3. Costs of production. Unit: mil./ha/year.

Items	IAM	ISH	RB
1. Variable cost [1]	6.34	597.98	44.87
Hired labor	0.11	30.19	3.32
Post-larvae shrimps	2.79	96.89	-
-Post-larvae crabs	2.48	0.00	-
Rice varieties	-	-	3.15
Formulated feed/rice bran	0.41	243.11	-
Miscellaneous	0.34	0.00	-
Lime	0.20	11.20	-
Sand	0.00	17.53	-
Chlorine (bacteria, virus control)	0.00	10.85	-
Drugs (snail, fungi control)	0.00	6.46	-
Antibiotics	0.00	42.33	-
Probiotic	0.00	39.78	-
Supplement	0.00	37.24	-
Electricity	0.00	57.32	-
Oil	0.00	6.97	-
Fertilizers	0.00	0.00	15.68
Pesticides	0.00	0.00	6.21
Rented machinery	0.00	0.00	16.50
2. Fixed cost (except depreciation)	1.96	18.43	1.11
Land rents (pay for private land owner)	0.35	0.00	0.00
Land rents (pay for government)	0.00	1.50	1.11
Excavator rents for maintaining pond's ditches	1.21	0.00	0.00
Interest (pay for loan)	0.40	16.93	0.00
3. Depreciation	0.63	33.30	0.00
Total cost	8.93	649.71	45.96
External input dependence (EID)	70.99	92.03	97.61

[1] Variable cost includes hired labor and excludes family labor. Source: Household survey, 2017–2018.

In this study, IAM was the low-input system in comparison with others, which was consistent with the findings of Rana and Chopra [55]. The system brings advantages for smallholder farmers who have limited access to capital in the communes. Mangrove farms play an essential role in supporting the natural input food and organic waste for food for marine areas in ponds and providing wild feedstock. Larsson and Folke [56] concluded that mangrove coverage of 25% per farm provides about 70% of its feed requirements. Furthermore, Gatune and Vanreusel [57] mentioned that the mangrove leaf litter longevity could be an explained component of the nutrient supply of the ecological system.

Regarding cost structures, the depreciation of IAM and ISH is estimated by the straight-line method with the consideration of different useful years depending on the kinds of assets or equipment. The depreciation cost of ISH was the highest among three groups, which included depreciable pond and channel concrete, machinery and equipment (generators, tanks, water pumps, pipes, aeration, oxygen meters, pH meters, and nylon matting), and other support infrastructure (tents, warehouses, gates, and fences). In RB production, farmers hire machinery (tractors, harvesters, and threshing) from private service providers in buffer communes. RB farmers pay rent for a package of several plots, including machinery drivers and fuel prices. Farmers do not own any machine or cows for rice production; therefore, depreciation does not exist in this system. The depreciation expenses of IAM include depreciable sluice gates, tents, and miscellaneous equipment (small boats, nets). Moreover, IAM farmers pay for the cost of maintaining pond ditches in farms. Every two or three years, farmers hire excavators to maintain the depth of the ditches. This cost is apportioned for each year (1.21 million VND/ha/year). IAM and ISH have to pay interest expense on their loans from banks and informal credit sectors. Meanwhile, RB farmers do not cover this cost due to smallholding production.

3.2.3. Use of Agrochemicals

Production quantity and profitability incentives have led farmers to use an extensive range of agrochemicals due to its immediate effects. ISH's shrimps are fed by additive nutrients (100% our respondents) and antibiotics (87.04%). These foodstuffs are mixed weekly for strengthening the health of shrimps, but without recordkeeping. Private input dealers' extension staffs visit farms frequently to guide farmers to use inputs until practices became habits. Farmers are unable to remember the types and ingredients of antibiotics and veterinary medicines. Hoang and Phi Nga [58] notified earlier that antibiotic residues were detected in the water surface of the XTNP due to shrimp rearing. Nevertheless, IAM did not involve these feed organisms.

RB farmers no longer use rotational cropping as a tool to manage pests and soil fertility. There was one indication that 100% of the surveyed farms were cultivated with pesticides as well as inorganic fertilizers. Moreover, we have found that an imbalance and overuse of chemical fertilizers (triple the urea) in RB compared with the local standard, as suggested by the DARD of Giaothuy district (see Table 4). According to the Food and Agriculture Organization (FAO) [1], fertilizers increase the amount of nutrients, as well as the eutrophication and pollution of estuaries, leading to a reduction of fish yield and coral. Önder and Ceyhan [59] warned that fertilizers are applied into rice plots to improve plant growth, but misuse can have side effects that include soil washing, as well as contamination to ground water, the sea, and water organisms. Using excessive nitrogen-based fertilizers might contribute to soil washing, contaminating the ground water and sea [60]. Organic fertilizers are well-balanced for long-term soil fertility. However, only 32.3% of rice cultivators used this nutrient source. As concluded earlier by Kamoshita [61], there are similarities regarding the use of inorganic fertilizers in the buffer zone communes and those in the outer areas.

Table 4. Utilization of synthetic fertilizers in rice production. Unit: Kg/ha/crop.

Indicators	RB	Local Standard Recommended [62]
Compound NPK	399.73	694.50
Urea (N)	371.06	111.12
Potassium (K)	99.75	138.90

NPK: Nitrogen–phosphorus–potassium fertilizer. Source: Household survey, 2017–2018.

Pesticides are for harmful insect elimination, but pesticide runoff contributes to surface water contaminants and has negative effects on human health. Pesticides do not kill only harmful targets: they kill harmless habitats as well. Our results further show that all of the RB farmers in the XTNP area routinely used numerous chemical pesticides. The use of pesticide mainly based on announcement from local loudspeakers of the CAB and CAC than farmers' field visits. Rice growers no longer practiced any integrated pest management (IPM) techniques to protect the natural barriers and minimize pesticide usage. Pesticide use as the end-of-the pipe of solutions to eliminate pests, golden snails (*Pomacea canaliculata*), and rats because of their immediate effectiveness and consumption of less time. The utilization of chemical fertilizers and pesticides in the XTNP area is recommended by public extension staff, but is not enforced [62,63]. There is no difference between pesticide application in rice cultivation between the XTNP buffer zone and outer communes [61]. In recent decades, there has been an increase in pest incidence, but a lack of conservation agriculture programs based on site characteristics and the technological development in this wetland area.

3.2.4. Marketing Activities

Different farm managers have different interactions with the market. Farmers involved in ISH sold all of their products to distant middlemen at farms with preservation processes (keeping shrimp alive in cold room of trucks) provided by these collectors from many provinces in northern Vietnam as Haiphong, Hanoi, or Quangninh, etc. Nearly one-quarter (24.08%) of farmers have faced difficulty in price bargaining.

Culturists that belong to IAM farms sell their products to local middleman (71%) in buffer communes and distant collectors (29%) in Namdinh province. Only black tiger shrimps are preserved alive in small tanks that are attached to the motorbikes of buyers and then transferred to distant markets at Namdinh province or Hanoi. The other products (wild shrimps and fishes) are transported to village and commune markets without preservation. The majority (72.6%) of farmers reported a price squeeze. Only one farmer registered a patent to the Vietnamese Office of Intellectual Property, which was approved. Then he sold shrimp, seaweed, and other products at nearly double the price compared to other farmers. In order to increase value-added for products, he also applied other marketing activities including conservation, processing, and designing packages. He recognized the products as organic, natural tasty, and of considerable size compared with ISH shrimps. Basing primarily to the labels, these products were traceable. Moreover, he connected with final customers in online customer groups and food-safe interest groups with thousands of members.

RB growers sell about 40% of the harvested products annually to local private shippers at their farms or final customers in local markets in buffer communes. All of the farmers growing rice complained of a price squeeze due to the low and homogenous value of their products.

3.3. Performance

3.3.1. Farm Outputs

Due to economic viability, ISH has the most advantages in terms of production volume (see Table 5). However, its productivity was much lower than those recorded in four provinces of Vietnam, which was 11,500 kg/ha/crop in a 92-day production cycle with a stocking density of 109 PL/m^2 [64].

Table 5. Productivity and farm-gate price.

	IAM		**ISH**		**RB**	
	Productivity (kg/ha/crop)	**Price (1000 VND/kg)**	**Productivity (kg/ha/crop)**	**Price (1000 VND/kg)**	**Productivity (kg/ha/crop)**	**Price (1000 VND/kg)**
Target product	69.89	260	3745	136.5	6225	10
Co-products						
Crab	16.35	339	-		-	
Wild-catch shrimp	49.07	129	-		-	
Wild-catch fish	9.77	30	-		-	
Natural bivalve	17.78	5	-		-	
Natural seaweed	642.31	4.8	-		-	
Total	-		3745		6225	

Source: Household survey, 2017–2018.

RB's productivity was 6225 kg/ha/crop, which was lower than the average number over the whole Namdinh province (6952 kg/ha) [65], but higher than the Vietnam national average (5547 kg/ha [66]). IAM provided 69.89 kg of black tiger shrimp per ha, which was lower than those in the coastal forest of Camau province, which gained 300–400 kg/ha with an average stocking density from 1–6 PL/m^2 [67]. IAM is recognized as having a moderate contribution to the total shrimp count due to low productivity. On the other hand, it has the potential to provide steady food for households with diverse products and contribute to maintaining mangroves in XTNP—because clearing forest trees is restricted in the conservation area—and increasing awareness on benefits of mangrove by land owners.

3.3.2. Economic Performance

Economic analysis can provide a systematic evaluation of farm activities, which in turn can lead to better management strategies toward economic sustainability [68]. Although the ISH system appeared to have the smallest scale, it was the most productive among the three models as indicated in the Table 6. The ISH farms obtained the highest level of output value followed by RB and IAM.

Table 6. Economic performance of farming systems.

	Indicators	Unit	IAM	ISH	RB
1	All outputs *	mil./ha/year	32.99	1017	124.79
2	Variable cost *	mil./ha/year	6.34	597.98	44.87
3	Fixed cost (except depreciation) *	mil./ha/year	1.96	18.43	1.11
4	Depreciation *	mil./ha/year	0.63	33.30	0.00
5	Farm gross margin *	mil./ha/year	26.65	418.59	79.92
6	Farm net actual returns *	mil./ha/year	24.69	400.16	78.81
7	Farm net sustainable returns *	mil./ha/year	24.06	366.86	78.81
8	Sustainable family income *	mil./ha/year	24.06	366.86	78.81
9	Working hours of family labor *	hour/ha/year	471.07	2847	3111
10	Sustainable family income per family working hour	1000 VND	51.08	128.85	25.33

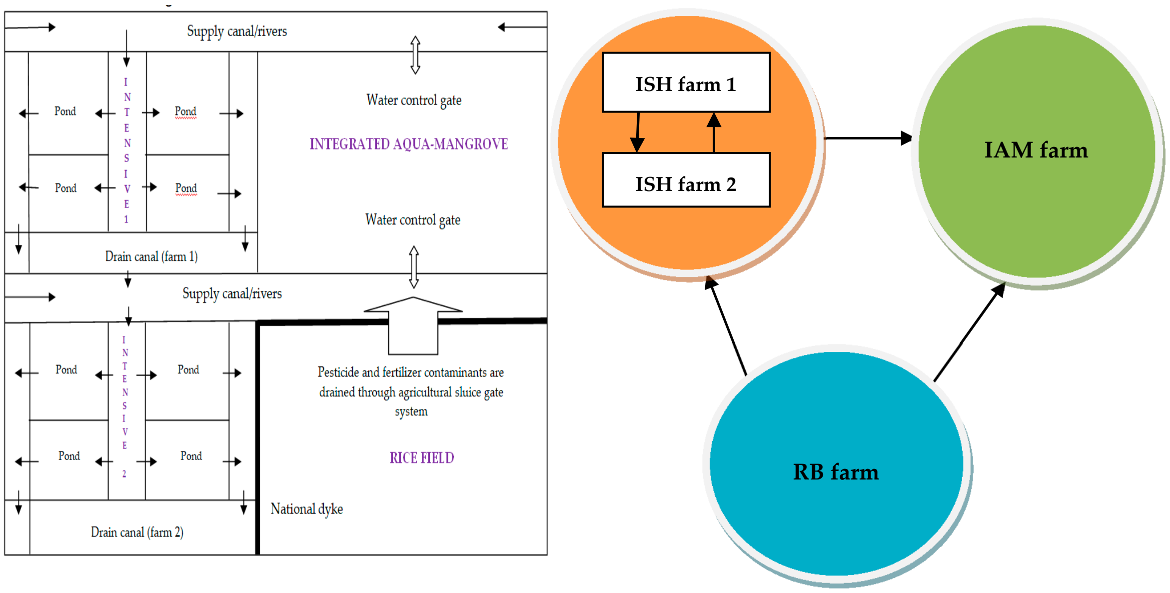
Different superscripts (*) from Kruskal–Wallis test denote significant difference between mean within rows ($p < 0.05$).
Source: Authors' calculation.

The results suggest that ISH is a more interesting model in terms of family income and labor productivity among the three systems, but the farmer households under this system should have more capital or better access to credit from banks. However, the economic achievement of ISH in XTNP was at a medium level compared with the other clusters in Vietnam [69]. The RB system had higher values regarding output and sustainable family income than IAM, but it required more family labor force per unit of land; therefore, rice farmers had lower labor productivity.

3.3.3. Interrelations between Systems

Farmers were asked about the serious problems related to their farming systems. Out of the responses, 90.47% of IAM and 77.78% of ISH culturists reported that their water intake was impaired in months in which pesticides were applied to their rice fields (March–April and August–September). The paddy fields were situated closely to the ISH farms and separated by a national dyke (10 m width) as visualized in the Figure 3a. Hoanhdong and Number 10 sluices belong to four drainage sluice system in five buffer communes of the XTNP. They are responsible for directly draining water from rice fields in the Giaothien commune to Tra and Vop rivers where provides intake brackish water for aquaculture. The statistics of the Giaothuy Irrigation limited company recorded that each sluice had dimensions of 4 m × 7 m (B × H) (B: width of the sluice; H: difference between river water level and canal design water level). Two of them covered a total of 1700 ha of drained area. Both of the two gates are controlled to open during pesticide application.

The frequency of water exchange in the aquaculture corporate in close proximity to the IAM (3 km) and ISH (1.9 km) with agricultural sluices might incur more effects from external pollution which illustrated in the Figure 3b. According to Nhuan and Ngoc [21], the concentration of pesticides and herbicides was higher than allowed in the XTNP area. Pesticides cause toxic pollution to the estuaries and inshore water, killing fish and leading to a reduction in fish yield, as mentioned by the FAO [1]. However, almost all of the rice practitioners were unaware of this alarming sign from their fields for aquaculture. They have used diverse pesticides for the control of weeds, pests, and exotic snails (*Pomacea canaliculata*) with a limited understanding of the ingredients. Both farmers and officials claimed that more pesticides have been adopted in recent decades due to increasing the farm labor costs and disease occurrence.



(**a**) (**b**)

Figure 3. Farm location and design. Note: (**a**) farm designation; (**b**) interrelations between systems.

Shrimp farming interacts with the environment across spatial scales regarding resource inputs and the production of waste [70]. The disposal of sludge and effluents from ISH ponds created pollution for not only themselves, but also some IAM farms nearby. The surveyed data indicates that intake water of 100% of ISH and 33.3% of IAM farms have been polluted by effluents from ISH ponds, since the majority of ISH farmers were reluctant to treat sewage before releasing it to the surrounding rivers. Water pollution impacts from shrimp production in the XTNP area have also been indicated earlier by Haneji, Amemiya [18]. They indicated that the surface water in rivers near the effluent disposal of shrimp ponds had higher values of BOD (biochemical oxygen demand) and COD (chemical oxygen demand) pollutant than national standards. Currently, farmers are not responsible for reporting water standard indicators for permitted organizations. Water quality regulations in terms of effluent standard and permits issued by the Vietnamese Ministry of Agriculture and Rural Development (MARD) [71], but they are implemented as advices for practitioners in this area.

4. Recommendations

Based on observations during the field surveys, we envision some measurements for economic development under the context of environmental protection for coastal areas related to promoting marketing tools, diversifying income sources, better strategies of price, and adopting better farm management practices. The recommendations that are proposed for both farmers and local authorities are as follows:

4.1. Marketing Activities, Diversifying Income Sources, and Cost Strategies

For IAM farmers, marketing tools of conservation, processing, and packaging are underdeveloped and often sold to middlemen, resulting in low value-added products and price squeeze issues. Labeling IAM products with Vietnamese Office of Intellectual Property certificates and selling them to the final customers instead of middlemen would be attractive tools to raise prices and solve the price squeeze problem. A parallel drying process should be applied to preserve shrimps and seaweed longer and sell them during off-season months. Over the long term, a sustainable certification program or environmental friendly labeling scheme could be promoted for IAM products due to its value and preference in the markets.

As noted by the council [72], monoculture can lead to an increase in soil erosion, pest damage, and chemical pollution. Bromley and Chavas [73] concluded that the diversification of crops can help farmers deal with drops in profits if the price for one crop is lower than average in a given time. Thereby, in order to overcome the weaknesses of mono RB, this research recommends alternative rotational cropping and intercropping. Rotational cropping could be implemented between rice and legumes or watermelon, which are popularly grown in the Giaoan and Giaoxuan buffer communes. The intercropping of rice and fresh aquaculture (perch) is already successfully applied in the Giaolac communal buffer zone. These practical tools help farmers diversify income sources in a year. For mono ISH culture, simultaneously raising shrimps with some male tilapias in the tilapia–shrimp ponds, which has been already applied by one farmer in XTNP, should be widely introduced by other farmers. The advantages of tilapias in the shrimp–tilapia system have also been mentioned earlier by Yi and Fitzsimmons [74]. It could be an alternative tool for reducing disease, using antibiotics, and improving water quality in ponds while at the same time enhancing economic returns for farmers.

The collective power of the farmers that belong to the three farming systems was relatively weak, as there have been no market farmer groups in the area. Hence, a farmers' market association should be created in the area to increase the voice of smallholder farmers.

Appropriate cost strategies also help farmers gain a higher level of profitability. In the case of RB production, a lower cost of nitrogen dosage and precise fertilization can help reduce the input costs as well as EID. Moreover, an increased rate of IPM application could also contribute to reducing the cost of pesticides in the long term. Rotational cropping also contributes to better soil health and reduced fertilizer costs in the RB system. In the case of ISH, promoting probiotics, restraining antibiotics, and effective formulated feed use can help farmers reduce costs, achieve higher incomes, and reduce side effects on the environment. In the IAM system, maintaining more forest coverage would generate more natural food within the system and reduce the cost of additive rice bran and formulated feeds for farmers.

4.2. Environmentally Friendly Farming Practices and Management

Existing farm activities are still conducted toward a manner of profitability that may broaden the gap between development and conservation. Promoting better farming practices can contribute to achieving higher yields while at the same time ensuring environmental protection. This research revealed that IAM is more sustainable than ISH and RB since it is less dependent on purchased costs; however, its productivity was low. Hence, we propose maintaining more trees in IAM farms, as it can contribute to achieving sustainable production capacity and providing more places for migratory birds. An implication based on optimal proportion was initially suggested by T.D. Truong [75], who indicated that mangrove coverage of approximately 60% could enable farmers to reach the highest level of output and profit.

The adoption of antibiotics and veterinary medicines in the ISH sector are the factors increasing the costs and high potential side effects for coastal wetland. More seriously, sludge and effluent disposal from ISH ponds are not monitored stringently by any institutions. Hence, the findings suggest that the implementation of best management practices (BMPs) in aquaculture would be a practical means for preventing negative impacts while ensuring economic efficiency in coastal aquaculture, as presented by Boyd [76]. In addition, treated and recirculated pond sludge was another technical resolution—previously mentioned by Hossain [77]—that can be considered another measure for the reduction of sewage pollution in the area. More importantly, water quality restriction regulations for shrimp aquaculture in Decree No.22/2014/TT-BNNPTNT approved by Ministry of Agriculture and Rural Development (MARD) [78] should be assured for enforcement at the farm level in the site.

We have found an imbalanced use of synthetic fertilizers in surveyed RB systems. Hence, this research suggests that cooperation between XTNP management experts, the CPC, the CAB, and the CAC ought to be required and re-established in order to stringently control whether local farmers follow government standards. Furthermore, precision farming or precision agriculture concepts should be introduced step by step in the coastal conservation zone to monitor the excessive use of urea [79]. Another challenge of RB culture is that farmers do not apply the IPM tool to protect the natural population. The pesticide runoff from the rice area has had documented effects on IAM (90.47%) and ISH (77.78%). According to the council [80], IMP can improve financial performances by reducing the pesticide input cost, pest population, and crop damage by pests. Thus, ecologically-based IPM should be urgently implemented in the area to enhance habitats and species in the surrounding zones and use plants as natural pesticides. This is imperative to strictly control chemical pesticides, and therefore contributes to the successful coexistence of the three systems.

5. Conclusions

The main purpose of this study is to assess the dynamics of farming systems through the adoption of SCP analysis. Three main farming systems were analyzed in the coastal XTNP with a substantial focus on cropping and aquaculture production. We conclude by emphasizing the outstanding facets of diverse coastal systems reflecting farming practices, whole-farm performance, and interrelation among the systems.

ISH required the highest production cost with a heavy reliance on artificial inputs; however, it also gained the highest net sustainable returns and sustainable family income in comparison with the other systems. The RB sector was cultivated to ensure food security for households, but its cultivators had the least labor productivity. IAM depended the least on artificial inputs and produced various ranges of products.

The production systems are economically important for local inhabitants, but the problems that arise from their unsustainable practices are very concerning. The adoption of antibiotics and veterinary medicines without careful record keeping in the ISH were recognized as potential side effects for environment and human health. More seriously, sludge and sewage from ISH farms were released to public rivers, which impaired intake from water sources for ISH and IAM. In surveyed rice plots, the results indicated that 100% of the farmers used pesticides as well as chemical fertilizers. Moreover, there has been an imbalance and excessive utilization of synthesis fertilizers. Besides, farmers no longer applied IPM tools to protect the natural population. The pesticide run-off from rice has been claimed to have effects on both ISH and IAM farms.

Our further results have demonstrated that the spatial proximity of farm designation was associated with unsustainable management practices, resulting in a low linkage between systems. Hence, we propose some recommendations to address the weaknesses of production regarding environmental friendly practices. Moreover, marketing activities, diversifying income sources, and forming farmers' market groups are necessary for economic development prospects.

However, this research has limitations related to assessing the social–economic and institutional elements of SCP in farming systems, as well as analyzing the factors influencing SCP, including market supply, demand, and public policy. This implies that future studies should focus on the subjects of corporate supply–demand and agricultural policies (regulation, taxes, subsidies, information provision, etc.) that affect SCP to provide broad view of sustainable development.

Author Contributions: Conceptualization, P.L., H.C.T. and T.T.N.N.; Methodology, H.C.T. and T.T.N.N.; Software, T.T.N.N.; Validation, T.M.H.H.; Formal Analysis, P.B.; Investigation, T.T.N.N.; Resources, P.L. and P.B.; Data Curation, T.T.N.N.; Writing—Original Draft Preparation, T.T.N.N.; Visualization, T.M.H.H.; Supervision, P.L. and H.C.T.

Funding: This research is funded by Vietnamese Ministry of Education and Training.

Conflicts of Interest: The authors declare no conflict of interest.

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