Analysis of the aquaculture sector in Ninh Thuan Province, Vietnam

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ANALYSIS OF THE AQUACULTURE SECTOR IN NINH THUAN PROVINCE, VIETNAM

BRUNO CRAEYE

TRAVAIL DE FIN D'ÉTUDES PRÉSENTÉ EN VUE DE L'OBTENTION DU DIPLÔME DE MASTER BIOINGÉNIEUR EN SCIENCES AGRONOMIQUES, À FINALITÉ.

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RÉSUMÉ

L'aquaculture joue un rôle de plus en plus important dans l'approvisionnement en poisson pour la consommation humaine et est considérée par certains comme une potentielle réponse à la demande alimentaire mondiale. Cependant, les impacts négatifs de l'aquaculture sur son environnement ont été mis en exergue par un grand nombre d'études. Le Vietnam, avec ces 3200 kilomètres de côte, possède un potentiel aquacole important, dont l'activité s'est développée exponentiellement ces trente dernières années. Comme conséquence de ce développement, le pays fait face à des répercussions néfastes telles que la salinisation des sols, la pollution de l'eau destiné à la consommation humaine, l'eutrophisation et la nitrification des eaux.

Dans ce contexte, le projet « RENEWABLE » a pour objectif de recycler les eaux usées de la crevetticulture en utilisant les microalgues pour valoriser les nutriments contenus dans celles-ci et de propager cette technologie dans la province de Ninh Thuan. Cette étude fait partie du volet socio-économique attaché au projet. L'objectif est d'effectuer une analyse du secteur aquacole de la province en déterminant la rentabilité économique des exploitations crevetticoles, en soulignant les limites des zones de production et en mettant en avant les obstacles à une aquaculture plus soutenable.

Pour atteindre cet objectif et obtenir un échantillon représentatif de la situation provinciale, deux communes ont été sélectionnées en fonction de leurs localisations et de leurs productions actuelles. Vingt-neuf agriculteurs furent sélectionnés aléatoirement et interviewés sur des questions économiques.

Ainsi, la production à Phuong Haï peut être caractérisée comme à faible capital, à plus faible intensification et aux résultats économiques très variables. Le coût de production est plus faible mais le prix de vente des crevettes l'est également. Les revenus tirés de l'activité sont donc faibles. Les problèmes d'irrigation, de pression des maladies, de la qualité des larves, de sécheresse, de pollution et de salinité rendent la production très risquée dans cette commune.

Pour la commune d'An Haï, la production est très intensive avec des installations et des investissements plus récents, des hauts rendements et des profits importants. Néanmoins, le coût de production plus élevé rend les producteurs dépendants des prix du marché.

Enfin, les obstacles à une aquaculture soutenable tels que le manque d'infrastructure, l'utilisation hasardeuse de certains produits vétérinaires et la volonté des producteurs ont été soulignés.

ABSTRACT

Aquaculture plays an important role in the supply of fish for human consumption and has been in recent years considered as a potential answer to the world food demand. However, negative impacts of aquaculture on the environment have been demonstrated in several studies. Vietnam, with its 3,260 km of coastline, offers great potential for aquaculture, which has developed exponentially in the last decades. Consequently, the country also faces the adverse impacts of aquaculture such as the salinisation of soils, pollution of water for human consumption, and eutrophication and nitrification of effluent receiving systems.

In this context, the project called 'REmoval of NutriEnts in Wastewater treatment via microAlgae and BiofueL/Biomass production for Environmental sustainability in Vietnam' led by the University of Liège in Belgium and the Industrial University of Ho Chi Minh City in Vietnam aims to upcycle wastewater from shrimp farming by using microalgae in a high-rate algal pond and use this technology within the Ninh Thuan Province. This study as part of the socio-economic aspect associated to the project aims to analyse the aquaculture sector by assessing the profitability for shrimp producers and highlighting the challenges and obstacles to sustainability linked with this sector.

Based on this premise and to obtain samples representing the aquaculture situation in the province, two communes (Phuong Haï and An Haï) were selected based on their geography and current shrimp production. 29 farmers were randomly selected and interviewed to obtain information from questions relating to the economy.

As a result, Phuong Haï shrimp farming can be qualified with low capital requirement, lower intensification, and highly variable economic results. The cost of production is small, but the selling price is also, which makes farm profits low. Irrigation problems, disease pressure, poor larval quality, drought, and pollution and salinity issues make production in this area hazardous. In contrast, An Haï shrimp farming can be characterised by an intensified production with recent installations and high yields and returns. Although profits are important, farmers in An Haï are not immune to a rise in the price of feedstuff or a fall in the price of shrimp. The main obstacles to sustainable aquaculture in Ninh Thuan Province, as the survey highlighted, are the lack of infrastructure, wastewater directly discharged into the outside environment, the hazardous use of medicine, and the willingness of producers.

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1 INTRODUCTION

1.1 RENEWABLE PROJECT

This master's thesis is a contribution to the project called 'REmoval of NutriEnts in Wastewater treatment via microAlgae and BiofueL/Biomass production for Environmental sustainability in Vietnam' (RENEWABLE) led by the University of Liège (Belgium) and the Industrial University of Ho Chi Minh City (Vietnam). The RENEWABLE project aims to couple wastewater treatment and the production of microalgae-based biomass valorisation as an effective way to enhance inorganic nutrients removal (Nitrogen and Phosphorus) from aquaculture wastewater and to produce biofuel and animal feedstuff from biomass. The project is funded by the Academy of Research and Higher Education and coordinated by Professor Gauthier Eppe (University of Liège) and Professor Le Hung Anh (Industrial University of Ho Chi Minh City).

The specific objective of this project consists of demonstrating the feasibility of using this microalgae method to reduce pollution in aquaculture wastewater discharged into coastal areas and of disseminating this microalgae technology to farmers. The beneficiaries identified are farmers, local authorities, shrimp producers, and the shrimp industry. Two laboratories are being set up as part of the project. The pilot lab is located in Ho Chi Minh City on the premises of the Industrial University of Ho Chi Minh City, and the field pilot is located in a marine seed-breeding centre in Ninh Thuan Province.

The project includes a socio-economic component with the purpose of collecting social and economic data from the aquaculture sector, preparing feasibility studies, and supporting the dissemination of the technology to the regional government and aquaculture farmers. As part of this component, my master's thesis aims to carry out an analysis of the aquaculture sector in the province of Ninh Thuan. The understanding of the aquaculture situation in the province is essential to enable the development of a future implementation strategy. Moreover, this work highlights the challenges of the aquaculture sector, the barriers to sustainability, and the limits that could be faced by the project during this implementation in Ninh Thuan Province.

1.2 SUSTAINABLE AQUACULTURE

According to the *State of World Fisheries and Aquaculture 2018*, aquaculture plays an important role in the supply of fish for human consumption. As we can see in the graph below, capture

fishery has been relatively stable since the late 1980s, while aquaculture production has considerably increased. In less than 20 years, aquaculture production has increased from 32.42 million tons in 2000 to 80.03 million tonnes per year, contributing to 46.8% of the global production of capture fisheries and aquaculture combined in 2016 (FAO, 2018).

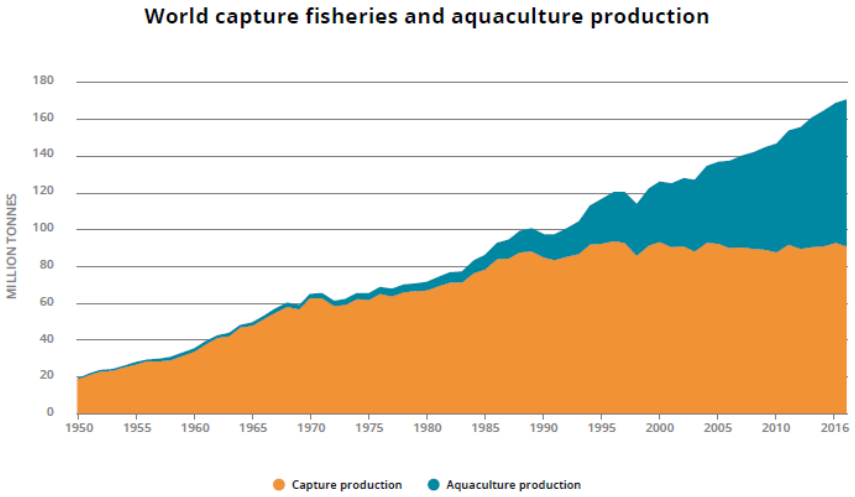


Figure 1: World capture fisheries and aquaculture production (FAO, 2018)

In the last decades, aquaculture has been considered as a potential answer to the world food demand. Indeed, with the percentage of fish stocks fished increasing at an unsustainable level, reaching 33% in 2015 compared to 10% in 1974, aquaculture is destined to play a key role in supplying the market. However, the impact of this practice on the environment cannot be neglected. Aquaculture is responsible for diverse problems connected with the health of the environment.

The essentially negative impacts due to aquaculture are as follows (Martinez-Porchas & Martinez-Cordova, 2012):

1. Salinisation/acidification of soils
2. Pollution of water for human consumption
3. Eutrophication and nitrification of effluent receiving ecosystems
4. Ecological impacts caused by inadequate medication practices
5. Ecological impacts in natural ecosystems because of the introduction of exotic species
6. Changes in landscape and hydrological patterns
7. Trapping and killing of eggs, larvae, juveniles, and adults of diverse organisms
8. Negative effects on fisheries by habitat modification; reduction of wild larvae; use of fish meat or fish oil as feed, placing pressure on pelagic fishery stocks (Naylor et al., 2000). These effects are summarised in figure 2, which illustrates the ecological links between intensive shrimp and fish aquaculture and capture fisheries.

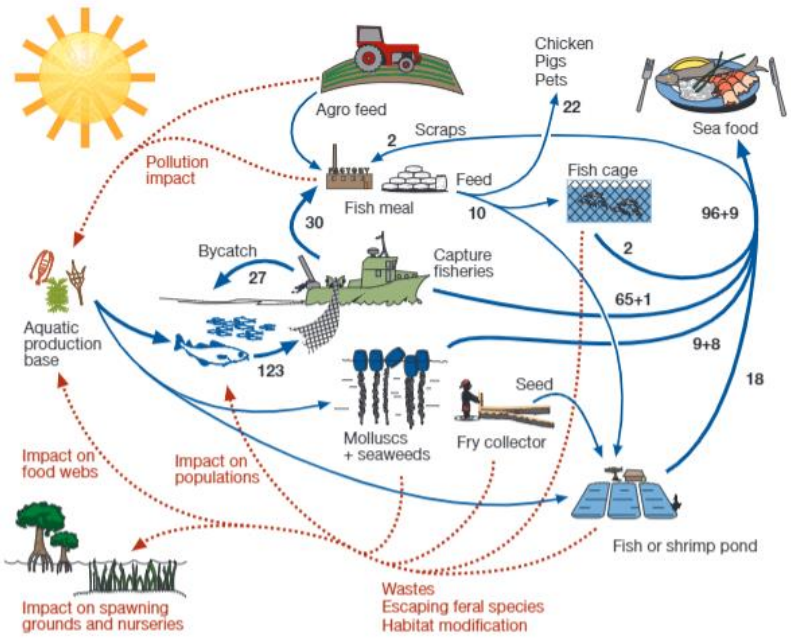
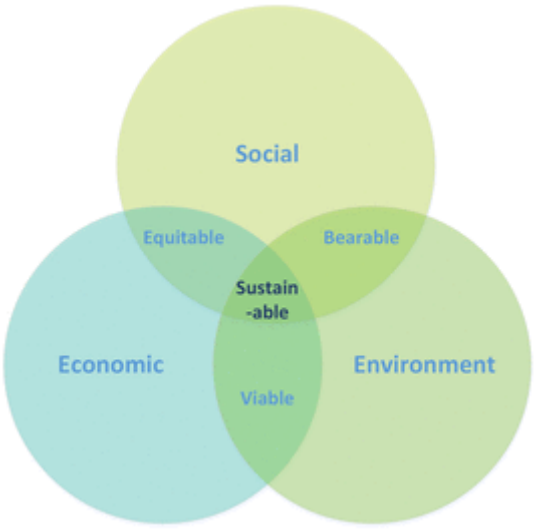


Figure 2: Ecological links between intensive shrimp and fish aquaculture and capture fisheries ***(Naylor et al., 2000)***

It is therefore important to develop environmentally sustainable aquaculture. The term 'sustainable' has been defined in a number of ways:

In 1987, the World Commission on Environment and Development defined sustainable development simply as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development, 1987).

Sustainability is generally described in term of three pillars: environment, economy, and society. This may be illustrated with a sustainability Venn diagram, as presented in figure 3 below:



Source: *www.circularecology.com*

Figure 3: Sustainability Venn diagram

The Food and Agriculture Organization of the United Nations (FAO) defines sustainable development as 'the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry, and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technologically appropriate, economically viable and socially acceptable'.

More specifically, FAO defines sustainable agriculture and rural development as processes that meet the criteria as cited: 'They ensure that the basic nutritional requirements of present and future generations, qualitatively and quantitatively, are met while providing a number of other agricultural products; they provide durable employment, sufficient income and decent living and working conditions for all those engaged in agricultural production; they maintain and, where possible, enhance the productive capacity of the natural resource base as a whole, and the regenerative capacity of renewable resources, without disrupting the functioning of basic ecological cycles and natural balances, destroying the socio-cultural attributes of rural communities, or contaminating the environment and they reduce the vulnerability of the agriculture sector to adverse natural and socio-economic factors and other risks, and strengthen self-reliance'.

Aware of the problems caused by overfishing and aquaculture, 170 countries, members of the FAO, adopted the Code of Conduct for Responsible Fisheries in 1995. This code, which is voluntary rather than mandatory, aims to set out principles and international standards and to provide a reference framework for national and international efforts (FAO, 1995).

In addition to this code, certification has an increasingly important role in the aquaculture market and contributes to a move towards more sustainable aquaculture. Examples of certifying organisations include the Aquaculture Stewardship Council or Best Aquaculture Practices. The demand for certified products is growing, with the main importing countries asking for more and more guarantees. Aquaculture certification appears to be a sustainability issue but, above all, an economic one.

This demand prompted Vietnam to create its own certification named VietGAP, which is an acronym for Vietnamese good agricultural practices. It is the set of criteria published by Vietnam's Ministry of Agriculture and Rural Development. The objective is to highlight producers who have adapted production techniques, promote better traceability, and protect the environment and health in the context of food safety (Vinacert, 2019)(T. B. T. Nguyen, 2015). Although international certifications are more attractive for export, this initiative appears to be a first step towards international certification for Vietnamese farmers. In September 2018, 390 shrimp, pangasius, and tilapia producers were VietGAP certified. (ASC, 2019)

2 VIETNAM: DESCRIPTION

2.1 GEOGRAPHICAL SITUATION

Vietnam, officially named Socialist Republic of Vietnam, is a country located in Southeast Asia between the latitudes 8°N and 24°N and the longitudes 102°E and 110°E. It shares its borders with Laos and Cambodia in the west and with China in the north. Vietnam covers an area of approximately 331,210 km². One of the particularities of this country is the length of its coastline, which is 3,260 km long (World Atlas, 2019).

Figure 4: Vietnam map (World Atlas)

2.2 POLICY

After periods of colonialism and decades of conflict, Vietnam was officially reunited in 1975 after a war with the United States.

In the 1970s and early 1980s, in Vietnam, the 'state planning committee' made economic decisions by establishing a plan that organised the activities of all other government departments. In this period, Vietnam was a centrally planned economy, which is an economic system in which economic decisions are made by a single authority such as the state or government rather than by the interaction between consumers and businesses. (Jim Chappelow, 2019)

In those years, 70% of the country's labour force worked in agriculture and depended on it. Despite this, the annual production was not sufficient to sustain the entire population. This led the state to import large quantities of food to meet its needs. At that time, the trade balance was largely in deficit. The sum of exports between 1976 and 1985 represented only one-third of the sum of imports over the same period. In addition, there were low foreign exchange reserves and high inflation due to the overspending of the state mechanism, which led to stagnation, crisis, and deteriorating living conditions. (Thang, 2000)

During the sixth party congress in December 1986, the government mandated a new policy, called Doï Moï, moving from a centrally planned economy to an open, market-oriented and globally integrated model (Thang, 2000)(Beresford, 2008).

This policy of openness, which has been gradual, has enabled Vietnam to develop rapidly. From 1986 to 1991, the measures to open up the market such as the liberalisation of the price of consumer goods, elimination of state subsidies for goods, sale of state-owned enterprises, and the adoption of a floating exchange rate were implemented (Thang, 2000).

The new policy abrogated agricultural collective, deleted price controls on agricultural goods, and allowed farmers to sell their goods in the marketplace. It fostered private businesses and foreign investment, including foreign-owned enterprises.

The program abrogated agricultural collectives, removed price controls on agricultural goods, and permitted farmers to sell their goods in the marketplace. It encouraged the establishment of private businesses and foreign investment, including foreign-owned enterprises. (Hays, 2008)(H. Nguyen & Grote, 2018)

From 1992 to 1996, the results of this policy is obvious. The annual gross domestic product (GDP) growth rate fluctuated around 9% during this period, as presented in the figure 5. (World Bank, 2019)

Figure 5: Vietnam GDP growth (annual percent) from 1985 to 2018

Source: World Bank national accounts data and OECD National Accounts data files.

From 1997, however, the economy was strongly affected by the regional financial and monetary crisis that hit most of the economies of Southeast Asia that year. As a result, economic growth from 1998 to 1999 decreased to half of what it was from 1995 to 1996.

Since the 2000s, Vietnam's annual GDP growth has fluctuated around 7%, which makes the country one of the fastest growing in the world, although it started from a very weak base due to the war. (Hays, 2008)

In recent years, Vietnam has become a member of several international organisations, such as the World Trade Organization, continuing the deregulation of its economy and the opening of its economy to foreign investment. In 2015 to 2016, the country concluded several free trade agreements including the European Union (EU) free trade agreement (which is still not ratified by the EU), the Korean free trade agreement, and the Eurasian Economic Union Free Trade Agreement.

Thus, Vietnam has strengths such as a development strategy based on the openness and diversification of its economy, its available workforce, its important natural resources, and its domestic stability. But Vietnam also faces limitations such as lack of infrastructure, the high share of state-owned enterprises in the capital, a fragile banking system with an estimated reserve around two and a half months of imports in late 2018, and some geopolitical tension with China (Coface, 2019).

2.3 POPULATION AND SOCIETY

The population was estimated at 97,040,334 in 2018 with a population density of 307.22/km² (CIA, 2018) (Unicef, 2019). This places the country in 15th place among the most populous nations in the world ((UNDP, 2019)). The population growth rate in 2018 was 0.9% with a median age of 30.9 years (CIA, 2018).Thus, the population is relatively young, which offers a high labour capacity. The population is not equally dispersed. The highest density of population is located along the South China Sea with the Mekong Delta (in the south) and the Red River Valley (in the north) possessing the largest concentration of people. The urban population represents 35.9% of the population. This percentage tends to increase with an annual rate of urbanisation of 2.98% (CIA, 2018).

Political and economic reforms initiated in 1986 have transformed the country from one of the poorest nations in the world to a middle-income country in less than 30 years. This significant growth has significantly affected the Vietnamese population. The poverty rate has dramatically decreased from 58% to 8% between 1993 and 2018 (CIA, 2018), (UNDP, 2019).

With a life expectancy at birth of 73.9 years, an expected number of years of schooling of 12.7 years, and a GDP per capita of United States dollars (USD) 6,900 in 2017, the Human Development Index for Vietnam has a value of 0.694 (from a rate of 0.475 in 1990 to 0.694 in 2017), which ranks the country 116th out of 188. Thus, Vietnam has experienced an increase in

standard of living that has been followed by the improvement of many development indicators such as education or health as well as greater social security.

2.4 AQUACULTURE

2.4.1 Economic overview

The ideal location of Vietnam, which has a tropical climate, 3,260 km of coastline, and more than 1 million km² of inland surface, has enabled the aquaculture sector to develop significantly over the past 20 years. Hence, the area dedicated to aquaculture more than doubled between 1995 and 2013, and the intensification of production made it possible to significantly increase yields and total output (World Bank, 2016).

According to the general statistics of Vietnam, the area dedicated to aquaculture was 641,900 ha in 2000. This has evolved significantly to reach 1,105,000 ha in 2017. Over the same period, yields have soared. Thus, production of aquaculture was around 589,000 tons in 2000 and reached 3,835,000 tons in 2017, which represents an increase of 650%.

If we focus only on the evolution of shrimp production, we observe an even greater increase. As we can see on the figure 6, the area dedicated to commercial shrimp farming was 324,100 ha in 2000 and reached in 2017 an area of 704,700 ha. In terms of production, shrimp farming reached an annual production of 723,760 tons in 2017, whereas it was only 93,503 tons in 2000.

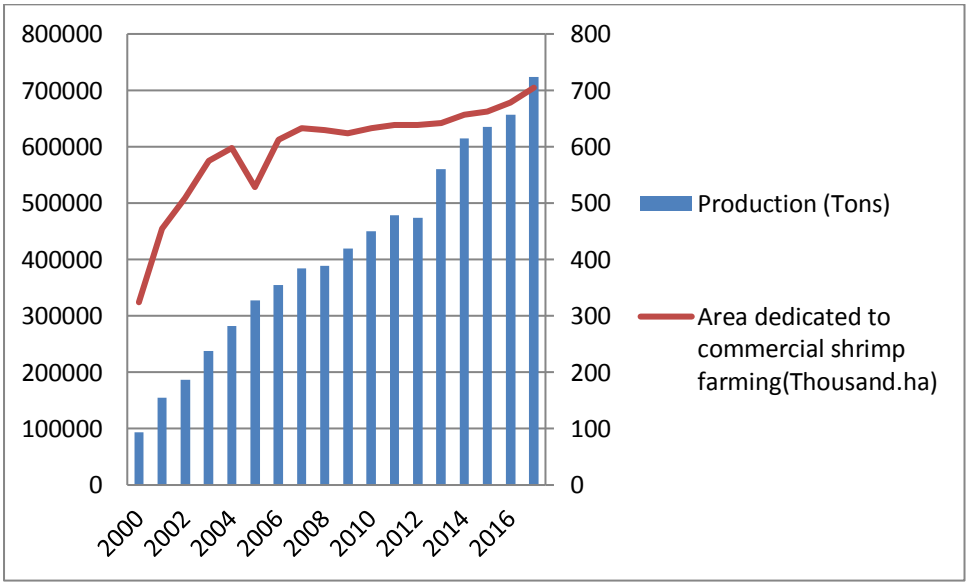


Figure 6: Evolution of commercial shrimp farming production and of the area dedicated to it in Vietnam from 2000 to 2017 (GSO, 2019)

Vietnam, which recorded exports worth USD 7.3 billion in 2016, is the world's third largest exporter of fish. In value terms, the country is the second largest shrimp exporter with 13% to 14% of the total world shrimp trade (VASEP, 2019).

Figure 7 presents the import market structure of Vietnamese shrimp in 2018. Vietnam's main customers are the EU, the United States, Japan, Korea, and China. The Quality standards of EU, US and Japan are very strict. Therefore, they can stop the import of Vietnam shrimp at any time if these standards are not respected. In the future, The economic war between the United States and China could have an impact on the importing markets of Vietnam shrimp. China which accounts for 14% of exports, import shrimp to process them in China and then export them processed. Following the increase in US customs duties, China could reduce imports of Vietnamese shrimp. (VASEP, 2019)

However, many recently signed trade agreements should allow Vietnamese aquaculture to continue its progress. One example is the agreement with the EU, which should make it easier for the country to sell in the EU through efforts on the quality and certification of its shrimp production. (European Commission, 2019).

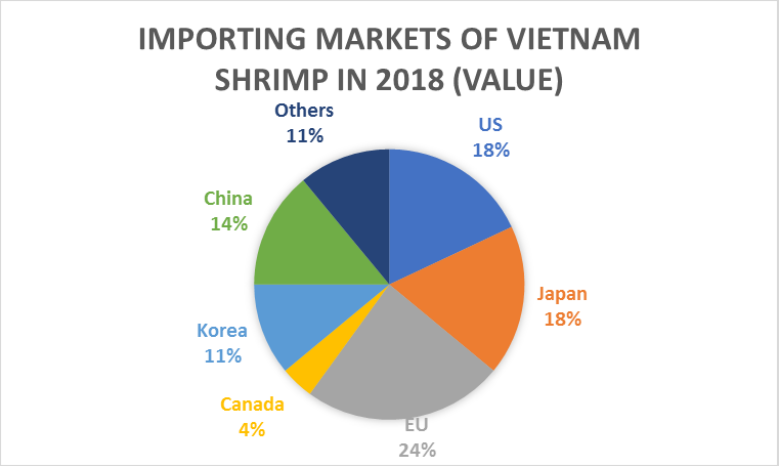


Figure 7: Representation of importing markets of Vietnamese shrimp in 2018 (VASEP, 2019)

2.4.2 Aquaculture practice

2.4.2.1 Cultivated Species

For Vietnam, the term 'shrimp' refers to the two most cultivated species in the country:

1. *Penaeus monodon*, known as black tiger shrimp

This species is naturally present in Vietnam. It is traditionally cultivated and has played a major role in the development of aquaculture in the country. Vietnam is the leading producer of black tiger shrimp in the world with a production of 300,000 tons per year.

2. *Penaeus vannamei*, known as whiteleg shrimp

The whiteleg shrimp is native to Central America. It was first introduced in Vietnam between 1997 and 2000. Since then, the production of this species has rapidly increased, mostly in the central and northern provinces of Vietnam.

The characteristics of this species make them particularly suitable for intensive production (Tien & Griffiths, 2009):

- Ease of breeding and domestication
- Ease of high-density culture
- Lower feed requirement than black tiger shrimp
- Tolerance of low water temperatures
- Tolerance of poorer water quality than black tiger shrimp

In the Mekong Delta, it was the Ministerial directive 228/CT-BNN-NTTS dated 25 January 2008 that allowed the production of this species in limited areas. As a result, production of whiteleg shrimp has dramatically increased in the Mekong Delta.

In 2013, for the first time in Vietnamese aquaculture history, production of whiteleg shrimp exceeded the production of black tiger shrimp (VASEP, 2019).As presented in the figure 8, in 2018, whiteleg shrimp production accounted for 69% of shrimp for export while black tiger shrimp production accounted for 23%.

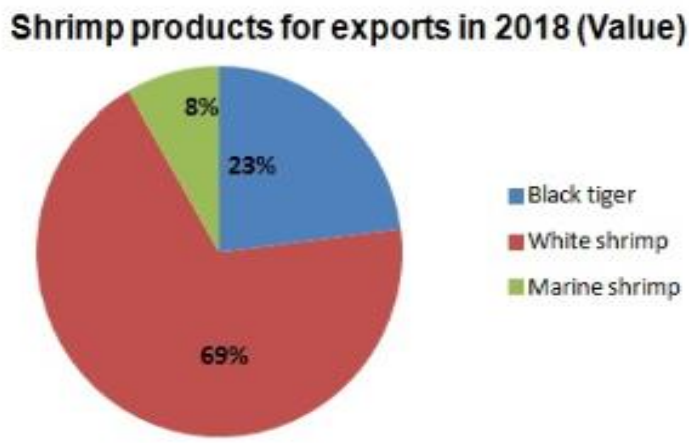


Figure 8: Pie chart of shrimp products for exports in 2018 in terms of value (VASEP, 2019)

2.4.2.2 ***Production systems***

Traditionally, shrimp farming in Vietnam has been based on extensive production systems. Over the last two decades, shrimp farming in Vietnam has gradually shifted to intensive production. This production system requires different feeds and new feed management strategies. However, various production systems of shrimp farming coexist. Indeed, according to FAO, growing techniques can be subdivided into three main categories:

- **Extensive**

Extensive system production is implemented in tidal areas where there is no artificial aeration or water pumping provided or they are minimal. It is a traditional production system for farmers located in coastal regions where saline intrusions are frequent during the dry season. These saline intrusions help to create the ideal brackish water for shrimp production. The size of the ponds is large with an average area of 5 to 10 ha and a depth of 0.7 to 1.2 m (FAO, 2003).

The shrimp are mainly fed through the natural food propagation from tides that bring in foods such as algae, phytoplankton, or crabs. Capital requirements for this type of system are low. Pond preparation and harvesting are the most important costs (Hop, 2012). Traditionally, naturally occurring shrimp larvae enter the pond and live there until harvested. Nowadays, the natural larvae stock is becoming smaller and smaller. This requires producers to sometimes add larvae from hatcheries to their pond.

- **Semi-intensive**

The larvae for a semi-intensive production system come from hatcheries and are grown at a density of five to six larvae per square metre for black tiger shrimp and 10 to 30 post-larvae per square metre for whiteleg shrimp. This type of production system requires less physical area than an extensive production system, with ponds around 1 to 5 ha. The natural larvae are supplemented with post-larvae from hatcheries. The inputs are higher because of the bigger stocking density that leads to higher management, feed, and labour costs.(Hop, 2012) Therefore, the production cost is higher than that for an extensive production system, with higher variable costs. In addition to natural food, the shrimp are fed with farm-made mixed and pellet feed (Tien & Griffiths, 2009).

- **Intensive**

Whiteleg shrimp are particularly adaptable to intensive shrimp farming. In recent years, many farmers have switched from producing black tiger shrimp to whiteleg shrimp for the reasons mentioned in the previous section. Intensive farming is commonly located in non-tidal areas because this type of production system requires ponds that can be completely cleaned and emptied between each crop. (FAO, 2003)

Ponds are generally small with an average size of 0.1 to 1 ha to optimise aeration and sludge disposal. The whiteleg shrimp stocking density is around 60 to 300 post-larvae per square metre. This type of production system depends upon heavy aeration for water circulation and oxygenation. A high stocking density implies a high oxygen demand.

The appearance of disease in intensive systems requires the use of domesticated disease-free and disease-resistant stocks. An intensive production system also requires constant

monitoring of feedstuff, water exchange quality, and aeration. All this implies higher production costs but average yields of around 7 to 20 tonnes per hectare per crop with a maximum of 30 to 35 tons per hectare per crop with two or three crops per year.(Hung & Quy, 2013)

A new technology used in some intensive ponds is called a 'bacterial biofloc system'. The principle is to create an environment that favours the use of nutrients by bacteria rather than algae by having a Carbon:Nitrogen ratio greater than 10:1 with low protein feeds. A floc of bacteria is formed and is used as feed for the shrimp. This technology reduces protein dependence, optimises economic efficiency, and improves the feed conversion ratio but requires a strict management of production parameters (Crab, Defoirdt, Bossier, & Verstraete, 2012).

2.4.2.3 Disease

Disease problems can be considered as the major concern for shrimp production and the first source of economic losses for farmers. Vietnam has faced many outbreaks in recent years due to viral infections. The viruses with the higher impact on shrimp production include white spot syndrome virus (WSSV); early mortality syndrome, also called acute hepatopancreatic necrosis syndrome (AHPND); Taura syndrome; and enterocytozoon hepatopenaei. The list of a large number of other diseases is exhaustive.

These diseases cause significant losses each year. Indeed, losses related to shrimp disease in the Mekong Delta in 2015 were estimated to be over USD 26 million for AHPND while the cost for WSSV in the same year was more than USD 11 million (Shinn et al., 2018). Thus, the losses are significant. It is therefore interesting to highlight the preventive measures to reduce the pressure of these diseases. These measures include:

- The use of specific pathogen-free (SPF) and specific pathogen-resistant (SPR) shrimp
- Promotion of good aquaculture practices such as proper pond preparation, the maintenance of good water quality, the use of high-quality feed
- Training of producers in disease detection
- Adequate irrigation infrastructure, limiting the risk of spreading disease
- Shrimp health management, monitoring, and record-keeping

3 NINH THUAN: DESCRIPTION

3.1 DESCRIPTION

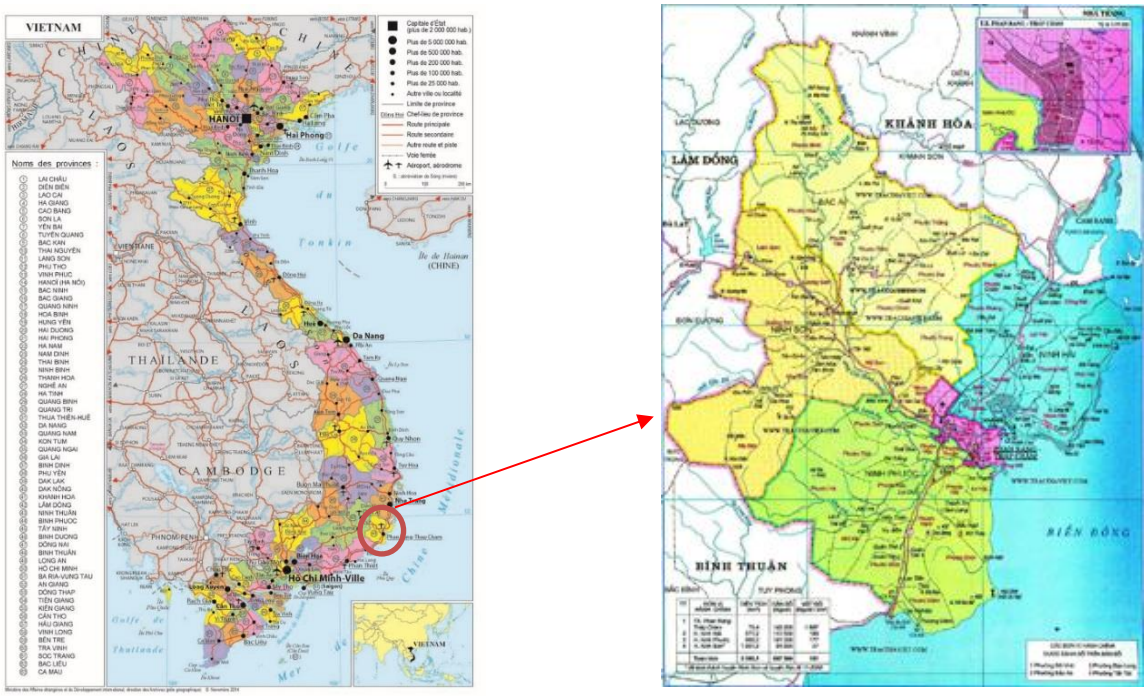
Ninh Thuan is a province in the south central coast, having a position from 11°18'14"N to 12°09'45"N latitude and 108°39'08"E to 109°14'25"E longitude, with a long coastline of about 120 km.

According to the annual statistical yearbook of Ninh Thuan, the whole province area is 335,534.17 ha, including an agricultural land area of 288,504 ha, of which aquaculture land (aquaculture) is 2,023.5 ha (2017) accounting for 0.70% of the natural land area; a non-agricultural land area of 31,686.66 ha; and an unused land area of 15,343.27 ha.

The province is subdivided into seven district-level subdivisions composed of six districts and one provincial city:

- Bác Ái
- Ninh Hải
- Ninh Phước
- Ninh Sơn
- Thuận Bắc
- Thuận Nam
- Phan Rang–Tháp Chàm (capital)

The two maps below show the geographic location of Ninh Thuan Province on the scale of the country and distribution of provincial districts in the province.



https://www.diplomatie.gouv.fr

http://www.ninhthuan.gov.vn

Figure 9: Administrative maps of Vietnam and Ninh Thuan Province

3.2 CLIMATE

Ninh Thuan has a tropical climate. The climate in the province is the driest climate in the country. The climate conditions are characterised by dry, hot, windy, and strong evaporation. As we can see on the graph below which represents the ombrothermal diagram of Phan Rang–Tháp Chàm, the rainy season is quite short in Ninh Thuan, and rainfall in the province is the lowest in the country.

SOURCE : HTTPS://WWW.CLIMATE-DATA.ORG

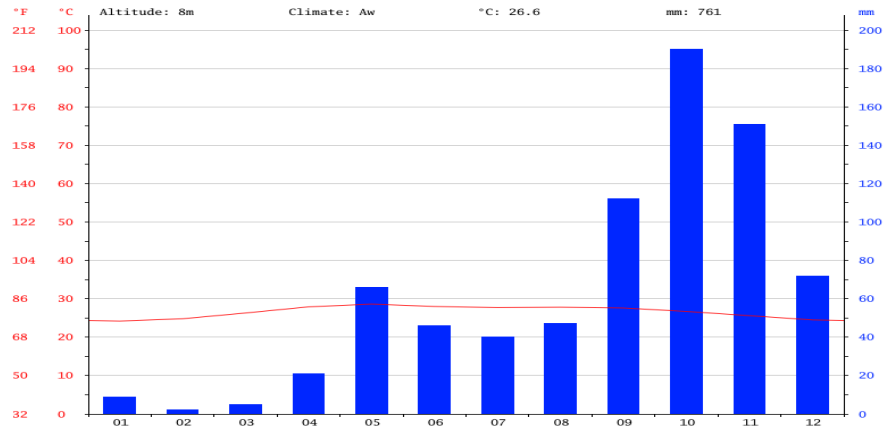


Figure 10: Ombrothermic diagram of Phan Rang–Tháp Chàm, Ninh Thuan

The following weather factors have directly affected farming in Ninh Thuan:

a. Wind: Due to the surrounding mountains, Ninh Thuan has a regimen of wind all year round and all day and night.
b. Low pressure of tropical storms: Ninh Thuan is not much affected by storms. The storm season starts from October and ends in December. November is the most concentrated month of storms.
c. Sunlight: Ninh Thuan has a long lighting period all year round, a long dry season starting from December and ending in April to July. There are up to 2,800 to 2,900 sunny hours per year with March as the sunniest month.
d. Temperature: The abundance of radiation brings high temperatures that are quite distributed throughout all months. In Ninh Thuan, the average annual temperature is over 26 °C and the total heat capacity is between 9500 °C and 10000 °C. The average temperature of the sea is 28 °C to 29 °C and its temperature is never lower than 26 °C.
e. Humidity: The annual average humidity of Ninh Thuan is very low, from 70% to 75%.
f. Low rainfall: The annual rainfall reaches 800–1,000 mm/year (Nha Ho: 744 mm; Phan Rang: 761 mm; Quan Tags: 737 mm; Ca Na: 814 mm; Nhi Ha: 835 mm). In addition, the rainy season is very short; there are many years without a rainy season.
g. Evaporation: The amount of evaporation in Ninh Thuan is quite high, about 1,800–1,900 mm/year, the highest in the country.

3.3 GEOGRAPHICAL CONDITIONS

3.3.1 Geographical context

The topography of Ninh Thuan is very diverse. It includes mountainous areas, semi-plain and plain areas, and riverside and coastal plains. The mountainous terrain accounts for more than 60% of the area, semi-mountains and hills account for 14.4%, and coastal plains account for 22.4%. The terrain tends to gradually descend from the northwest to southeast and the basin into the living area and the area of Phan Rang–Tháp Chàm.

The Ninh Thuan coastal area is a place where hot currents and cold currents are concentrated. The cold current creates rising water that is rich in nutrients, and the sea floor has coral reef distribution. Therefore, the Ninh Thuan sea water environment is naturally clean and convenient for farming most aquatic products and aquatic seed production.

3.3.2 System of rivers and streams

Due to the topographic characteristics of the province, most rivers and streams in Ninh Thuan are short and sloping, of small flow volume, and concentrated mainly in the rainy season (from October to December). In the dry season, a shortage of fresh water often occurs. The total catchment area of the main rivers is 3,600 km² and consists of two main river systems: the Cai Phan Rang River system and other independent river systems. Currently, on the systems of rivers and streams, dams and reservoirs have been built supplying irrigation water for production and daily life but not enough so to meet the demand for fresh water for aquaculture.

3.3.3 Groundwater

In terms of geological and hydrological conditions, the groundwater potential of Ninh Thuan Province is very low compared to other places, with only a third of the national average. In addition, groundwater is affected by salinity and has low mineralisation. Therefore, groundwater reserves are poor and are only exploited for small-scale households. But some areas are currently exploiting groundwater for aquaculture. With low reserves and the high water requirements of aquaculture, there is a risk of groundwater depletion in the future.

3.3.4 Infrastructure system

3.3.4.1 Traffic

Compared to the nationwide average, the number of provincial roads is low with an average of 0.24 km/km² and 1.61 km/1,000 people. The province has 174.5 km of national highways composed of National Highway 1A, National Road 27, and Highway 27B. There are also 10 provincial roads with a total length of 322.54 km, district roads with a total length of 189.9 km; urban roads, 128.24 km; and commune roads, 238.3 km.

3.3.4.2 Electricity

Ninh Thuan Province is supplied with electricity from the 220-KV and 110-KV national power grids with a direct supply from the Da Nhim hydropower plant that has a capacity of 160 MW. At present, the medium- and low-voltage electricity network reaches almost all aquaculture areas. However, there are still no three-phase electricity systems for production in some concentrated aquaculture areas.

3.4 SOCIAL AND ECONOMIC CONDITIONS

3.4.1 Population, labour, and employment

Ninh Thuan has a relatively small population compared to other provinces in the south central coast and southeast. The average population of the province in 2017 was 606,980 people, up 0.93% from 2016 including an urban population of 219,800 people, accounting for 36.2%, and a rural population of 387,200 people, accounting for 63.8%. The average population density was 179 people/km² while the average density in the country was 283 people/km² (General Statistics Office of Vietnam, 2017). The labour force was 352,400 people, accounting for 58% of the province's population, of which male workers accounted for 55% and female workers accounted for 45%. The labour force in urban areas accounted for 35.1% and rural labour force accounted for 64.9%. The percentage of trained employed workers at 15 years of age and above in 2016 was 15.4% (General Statistics Office of Vietnam, 2017).

The number of people from the age of 15 and over working in the economic sector in 2017 was 342,900 people (an increase of 7,500 compared to the number in 2016). Agriculture, forestry, and fishery workers accounted for 50.6% of the total working population, while the industrial and construction and the service sectors accounted, respectively, for 17% and 32.4% of the total working population of the province. The figure below presents the distribution of the total working population in Ninh Thuan for 2017.

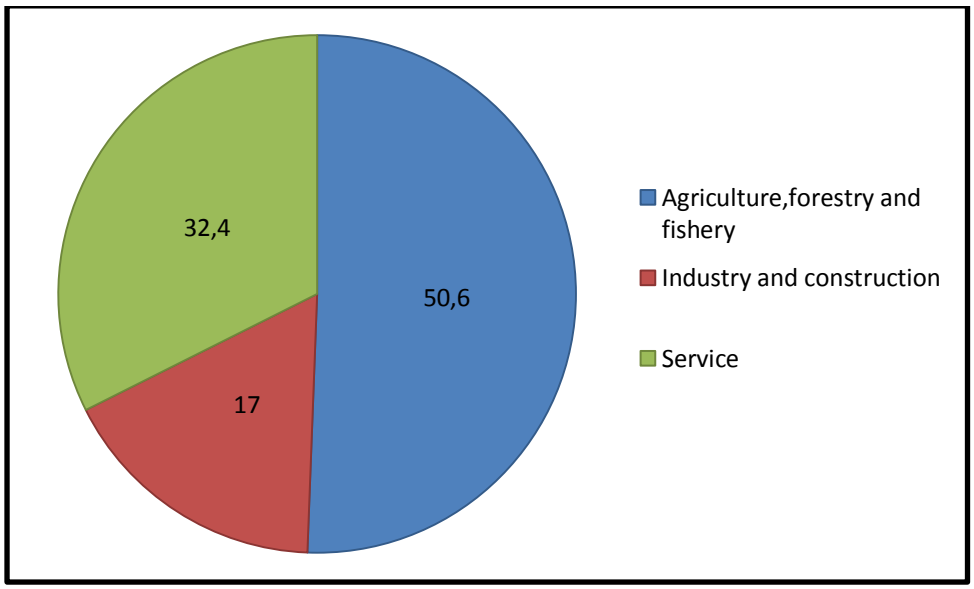


Figure 11: Distribution by sector of the total working population in Ninh Thuan

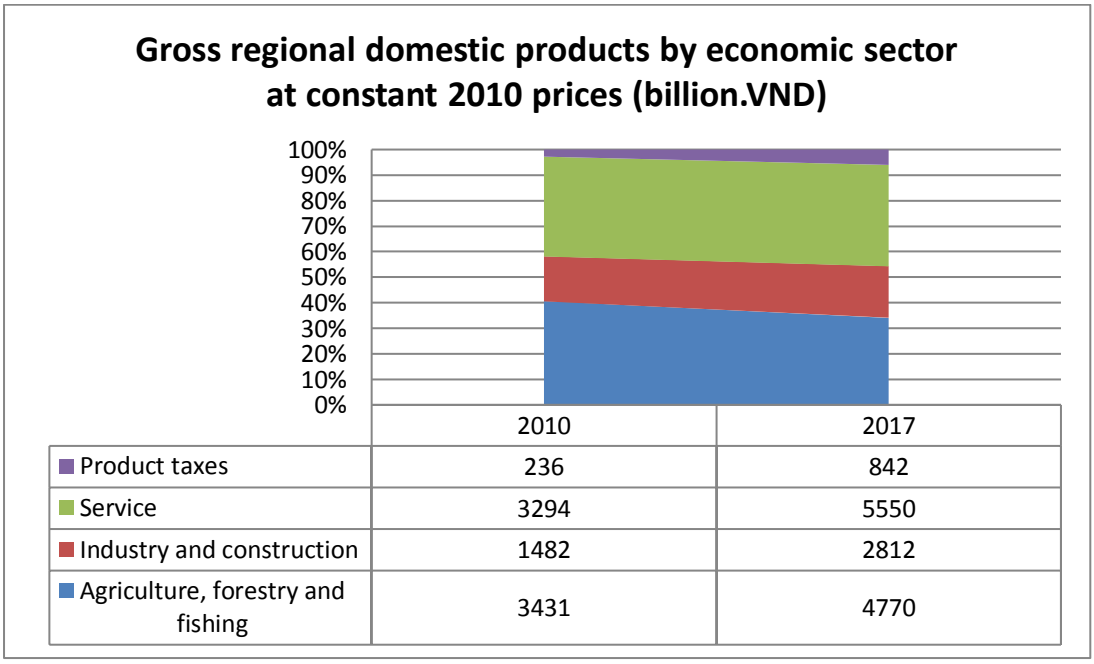
In 2017, the proportion of trained labourers in the province aged 15 and over was 14.3%, which is lower than in 2016 when the proportion was 15.4%. The proportion in urban areas is higher than the province average with 26% of trained labourers, while it is 8.1% in rural areas. The

unemployment rate of the labour force accounted for 2.93% of the population in 2017. This rate reaches 4.06% in the urban areas, while it is 2.93% in the rural areas.

3.4.2 Economics

In 2017, the gross regional domestic product of Ninh Thuan at a 2010 price comparison reached 13.984 billion Vietnamese dongs (VND), an increase of 1.65 times compared to in 2010. Figure 12 illustrates the evolution of the gross regional domestic product by economic sector at constant 2010 prices. In 2017, the agriculture, forestry, and fishing sector represented 36.03%, a decrease of 4% in comparison with the percentage in 2010, while the industry and construction sector showed an increase of 2.5% compared to in 2010 with 19.97% of the gross regional domestic product in 2017. Concerning the service sector, it decreased by 1% in the 2010 to 2017 period. Product taxes recorded the highest increase from 2.8% in 2010 to 6% in 2017. Overall, the farmer's sector is tending to decline in favour of the industry and construction sector, but the agricultural sector still represents the largest part of the economy in Ninh Thuan. Thus, the share of this primary sector in the provincial economy is significant compared to the share of this sector in the national economy. Indeed, the agriculture, forestry, and fishing sector represented less than 15% of the gross national domestic product in 2017.

SOURCE: NINH THUAN STATISTICAL YEARBOOK 2017



	2010	2017
Product taxes	236	842
Service	3294	5550
Industry and construction	1482	2812
Agriculture, forestry and fishing	3431	4770

Figure 12: Comparison of the Gross regional domestic product by economic sector at constant 2010 prices (in billions of VND) between 2010 and 2017

3.5 AGRICULTURE

The agriculture has an impact on aquaculture production and vice versa. Pesticide residues from rice crops can be a threat for shrimp production while the antibiotics used in aquaculture can cause pollution in rice crops.(Braun et al., 2019). Since rice crop requires significant irrigation, pesticide residues can easily spread through irrigation water and cause damage to aquaculture production. Decades ago, many farmers began producing shrimp by converting their rice fields into ponds. This has led to salinization of water and a decrease in rice yields in some areas.(Hishamunda, Bueno, Ridler, & Yap, 2011). Therefore, the cohabitation between these two productions is complex and requires adapted arrangements.

In 2017, the total area of annual crops was 86,989 ha. As in all of Vietnam, paddy rice was the main crop with a total area of 48,435 ha, which accounted for 55% of the total area of annual crops. Maize production also represented an important area with 13,079 ha. The table below shows the cultivated area of the main annual crops in 2017.

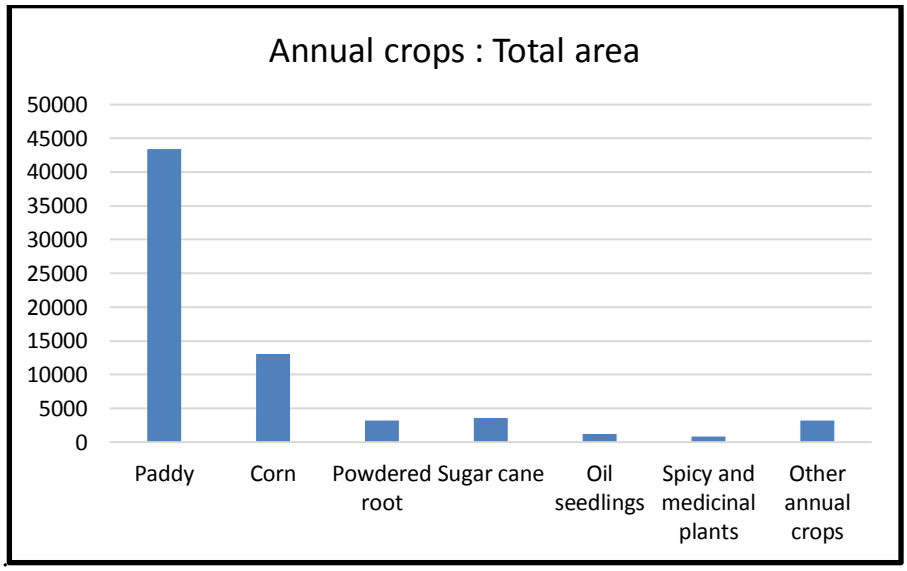


Figure 13: Annual crop area in 2017 in Ninh Thuan Province

4 CURRENT SITUATION OF AQUACULTURE: NINH THUAN

This overview of aquaculture is based on aquaculture annual reports written by the ministry of Agriculture and Rural department from 2012 to 2018 and on discussion with farmers.

4.1 CURRENT SITUATION OF BRACKISH AQUACULTURE

The purpose of this section is to highlight the main trends linked to the evolution of shrimp production and the farming area dedicated to this production in recent years. Figure 14 shows the evolution of production and of the total area dedicated to commercial shrimp farming. Globally, two trends can be highlighted: first, a significant decrease in production and surface area between 2014 and 2015, and second, an increase in production area that is not followed by an increase in production in 2018.

Between 2014 and 2015, the main reason for the decrease in production was the lower price of commercial shrimp. Sometimes the selling price fell to 86,000 VND/kg and the highest price was only 105,000 VND/kg (100 shrimp/kg), which is not much different from the product price. Indeed, combining the effects of drought, hot water, lack of freshwater production, the cost of inputs such as electricity, and the increase in feed prices, the calculation of economic efficiency was negligible. Therefore, most farmers reduced the size of the area dedicated to commercial shrimp farming by switching to farming other products such as lobsters, snails, or salt.

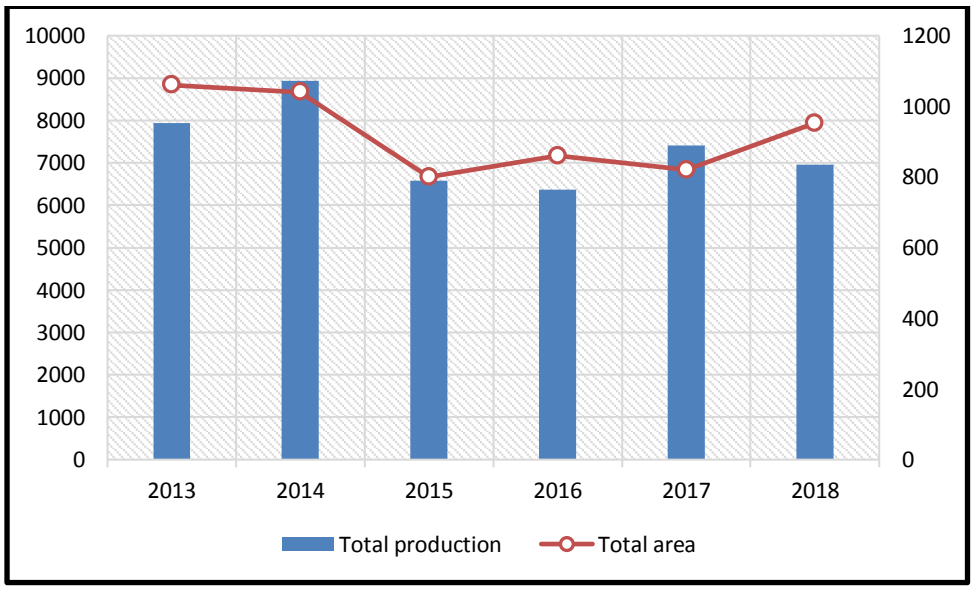


Figure 14: Production (tons) and area (hectares) dedicated to commercial shrimp farming (2013–2018) in Ninh Thuan Province

In November 2018, the farming area for commercial shrimp was 893 ha, including 32 ha of black tiger shrimp and 861 ha of whiteleg shrimp. The total farming area for 2018 was estimated to reach 952 ha, which represents 102.7% over the same period in 2017.

The estimated output for the year 2018 was around 6.957 tons. This result shows a decrease of the output compared to that in 2017. Indeed, the output in 2018 was estimated to reach 97.5% over the same period in 2017.

These results reveal an increase of the total farming area and a decrease of the yield in 2018 compared to in 2017. This phenomenon can be explained by:

- The selling price of commercial shrimp fell sharply during the peak of production (April to mid-June). During this time, the price of shrimp was around 70,000–75,000 VND/kg. The economic efficiency was negligible; some of the farmers even lost money. Then, farmers limited their investment. That was why Dam Naï farmers switched from intensive and semi-intensive systems to fewer intensive systems. This change resulted in lower crop yields.

- In addition, the unstable weather conditions, white spot disease, and acute hepatopancreatic necrosis occurred in most of the farming areas. Consequently, the area of diseased shrimp as of 2 November 2018 was 88 ha. Such a disease-impacted area resulted in losses in production and anticipated harvests and therefore lower yields.

4.2 SEAWEED

Seaweed production is mainly located in the Khanh Hoi, My Hiep (Ninh Hải), and Phuoc Dinh (Thuận Nam) in coastal areas. Seaweed farming benefits farmers thanks to its smaller vulnerability to natural disasters such as storms or flooding. Seaweed can be harvested year-round and has positively affected the environment.

Figure 15 shows the evolution of the production of seaweed in Ninh Thuan and of the area dedicated to seaweed farming. One trend stands out: Both surface area and production have tended to decrease in recent years. The surface area has thus fallen from 206 ha in 2013 to a minimum of 9 ha in 2017.

Figure 15 Production (tons) and area (hectares) of seaweed in Ninh Thuan Province (2012–2018)

According to annual reports from the aquaculture department of Ninh Thuan, this trend can be explained by the market volatility, the absence of a process to raise standards, the poor weather, and the appearance of disease as well as fish that eat algae. Under these conditions, farmers are reluctant to invest in algae. They no longer plant new trees, and production tends to decrease significantly. The small increase in production in 2018 is explained by the good weather and the more profitable selling price.

4.3 FRESHWATER FISH

Freshwater fish farming activities are mainly concentrated in the mountainous districts such as Ninh Sơn, Bác Ái, Thuận Bắc, etc., with traditional products such as carp, tilapia, catfish, snake, and is cultivated by intensive farming or intercropping fish and rice. Currently, freshwater fish in the province is mainly cultured according to household size, meeting the main local demand, so the area and output are negligible.

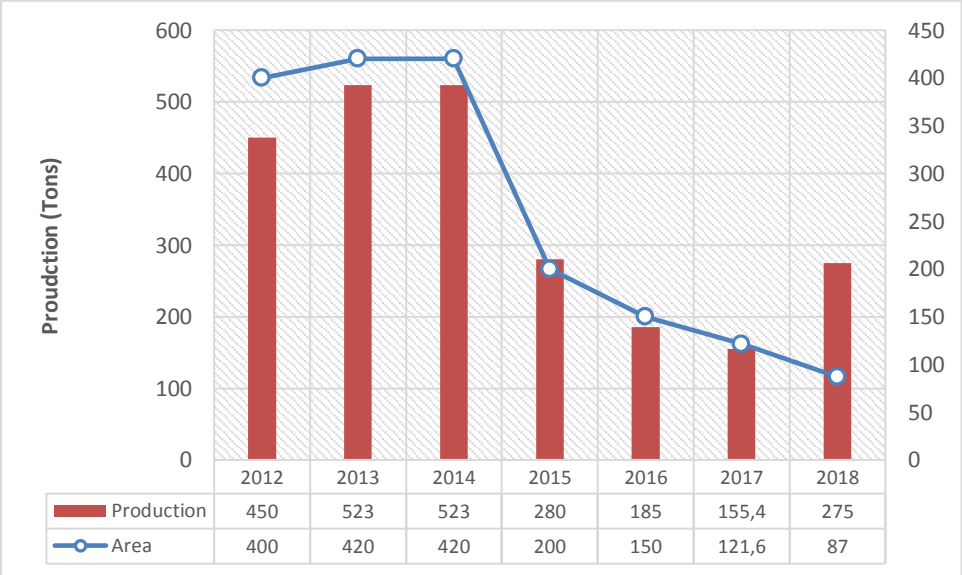


Figure 16 Production (tons) and area (hectares) of freshwater fish in Ninh Thuan Province

4.4 SNAIL

Snails are raised primarily in two forms: in earthen ponds (in the area of Tan An to Tri Hai) and cultured in sand ponds with canvas in Phuoc Dinh (Thuận Nam) and some communes along Dam Naï.

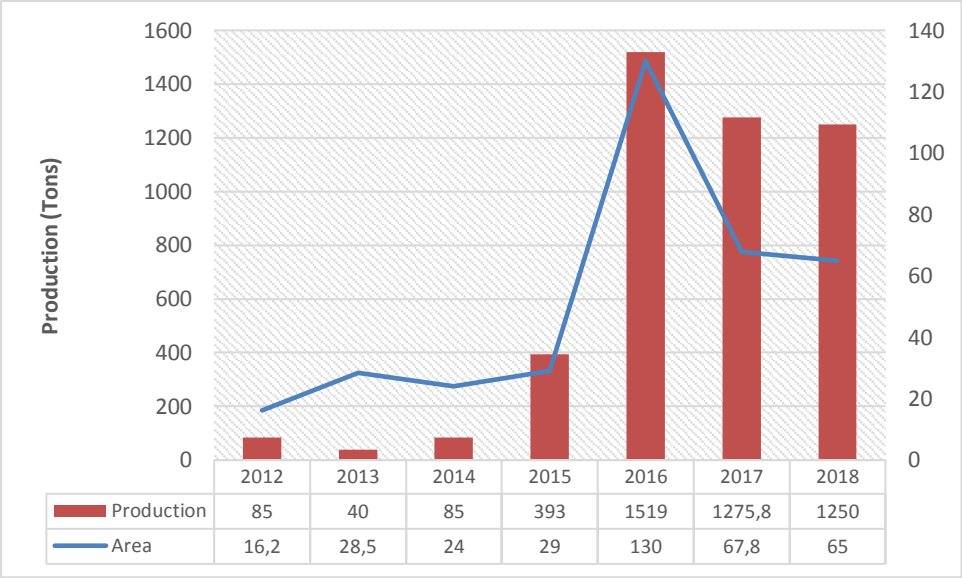


Figure 17: Production (tons) and area (hectares) of snail farming in Ninh Thuan Province (2012–2018)

Figure 17 illustrates the evolution of snail production and the area dedicated to snail farming. Globally, the production and the area have both increased in recent years. In 2012, production was 85 tons with an area of 16.2 ha and 125 cages, while in 2018, production was around 1,250 tons with an area of 65 ha. Production has increased very strongly, being 14 times higher in 2018 than in 2012. The area dedicated to production quadrupled between these two years. These increases illustrate that production techniques in the province have changed, moving more towards intensive production leading to higher yields.

Figure 17 also indicates that a large number of farmers started producing snails, particularly between 2015 and 2016. This trend can be explained by the following:

- With high yields and a high selling price, farmers producing snails were very profitable between 2014 and 2015. The success of these farmers convinced other farmers to produce snails too.
- The 2014 to 2016 period also corresponds to a period of decline for shrimp farming in Ninh Thuan. After years of loss and facing risks related to the production of shrimp, some agricultural farms switched to the production of snails.

Meetings with snail producers have put forward some advantages and disadvantages of snail production:

- Snails are more suited to a salty environment than shrimp. Difficult access to fresh water for some farmers in Nai Lagoon has convinced some of them to stop shrimp production in favour of snail production.
- Most snail producers export their snails to China, which is the main customer. In 2019, the increase in production and the stagnation of demand led to a decrease in the selling price. In addition, yields are low in 2019 according to farmers. Both of these factors have created a great amount of uncertainty for snail producers.

4.5 LOBSTER

Figure 18 shows the evolution of lobster production and of the number of cages dedicated to lobster farming in Ninh Thuan Province between 2012 and 2018. Globally, lobster production and the number of cages have tended to increase significantly in recent years after a period of decline between 2012 and 2015.

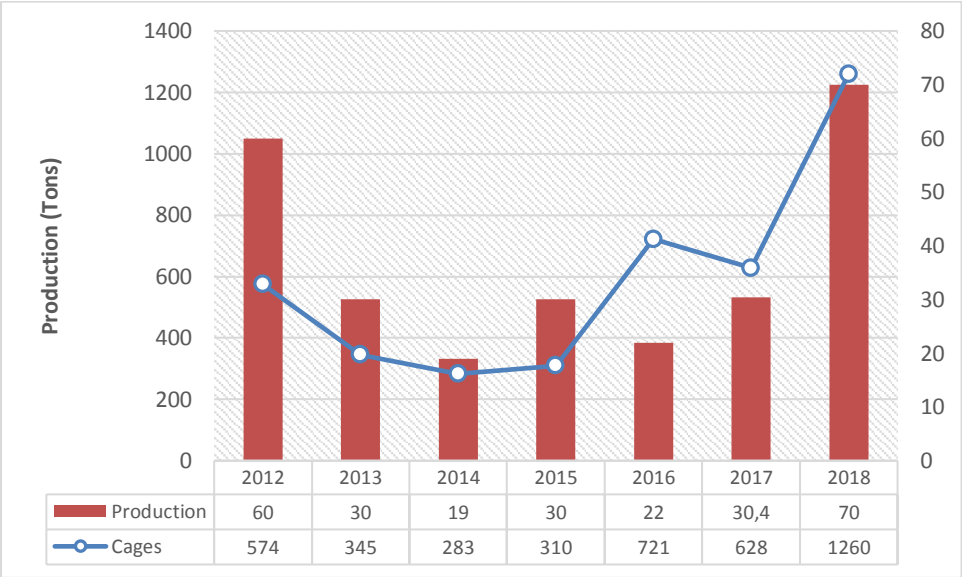


Figure 18: Production (tons) and number of cages of lobster farming in Ninh Thuan Province (2012–2018)

This period of drop-off is due to the relocation of a number of cages to a specific zone in Phan Rang Bay according to the socio-economic development plan of the province. The relocation process led to damages to the cages. Moreover, the relocation area was located in an open, uninhabited coastal area that had no shielding island and that is often influenced by strong winds. The traditional cages were not suitable to withstand these conditions. Therefore, the cages had to be moved during the south-wind season or when floods and storms occurred, creating an unsafe situation for farmers.

Moreover, the price of commercial lobster was unstable and tended to decrease, while feed prices and seed prices were becoming increasingly high. Therefore, most farmers reduced the number of cages or combined the farming of lobsters with the farming of other products to minimise risks.

The traditional species cultivated is the spiny lobster (*Panulirus ornatus*), but from 2016 onwards, many farmers started to produce green lobsters (*Nephropidae sp*). Farming rock lobsters can provide several benefits but is associated with potential risks and a large amount of capital, while the green lobster may be sold after 12 months rather than 18 months and is easier to raise, with fewer price fluctuations and low investment costs.

4.6 CRAB, OYSTER

The total farming area dedicated to oysters and crabs in 2018 was about 30 ha and concentrated mainly in Hon Thien, Go Den, and Phuong Cuu villages in Ninh Hải District. Larvae are mainly collected from the wild so the production scale depends on the natural reserve. Crabs are mainly cultured by extensive farming. In recent years, some Phuong Haï farmers started to produce black tiger shrimp in association with crabs. After the cultivation of whiteleg shrimp, the farmers produce both species in low density, which allows them to increase their income. Moreover, crabs and *Penaeus monodon* can be harvested progressively. Thus, the farmers can produce products until flood season occurs.

4.7 POST-LARVAE: PRODUCTION

4.7.1 Production sites

Ninh Thuan has 498 facilities of post-larvae shrimp with 1,200 hatcheries, producing almost 30 billion shrimp per year and meeting 35% of the country's demand. These larvae are mainly destined for the southern provinces in the Mekong Delta.

Ninh Thuan has three seed-production areas:

1. An Haï to Ninh Phước District

   The An Haï concentrated seed-production area was created in 2005 with the guidance of the Ministry of Fisheries (now the Ministry of Agriculture and Rural Development) in collaboration with the provincial people's committee. The area covers 125 ha, and the production capacity alone for this area is likely to reach 10 billion to 12 billion seeds per year (about 35% to 40% of the seed of the province). This area has attracted about a hundred larvae producers including large companies such as Viet-Uc, Grobest, and C.P. Group.

2. Than Haï to Ninh Hải District

   This area is the second largest production area of Ninh Thuan. It extends from Khan Nhon village in the Nhon Hai commune to the end of the My Hiep and Thanh Haï communes. This area has 60% of the province's hatcheries but contributes only 40% of the province's total production. The characteristics this area has are due to a lack of investment in infrastructure, which has caused spontaneous development such that most of the area's small facilities are fragmented. In addition, technical investment is small and the environment is increasingly polluted. The fragmentation of facilities and the avoidance of management by the state make this area difficult to manage.

3. Other areas

In addition to the two zones mentioned above, Ninh Thuan also has some less concentrated production areas that represent a production of approximately 1 billion to 1.2 billion seeds per year. These areas have no planned infrastructure. They do not produce at high efficiency and face many difficulties.

4.7.2 Production

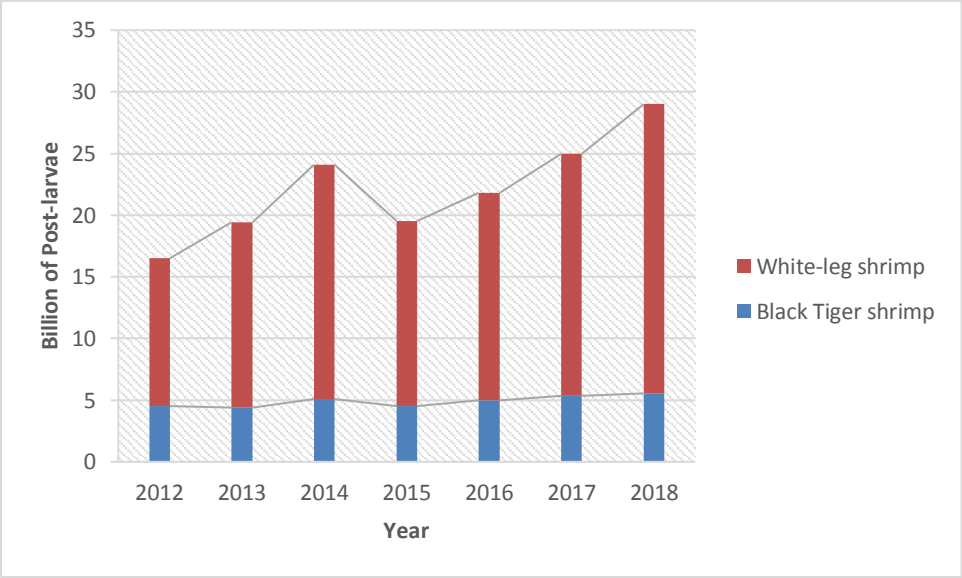


Figure 19: Shrimp post-larvae production in Ninh Thuan (2012–2018)

Figure 19 illustrates the evolution of shrimp seed production in Ninh Thuan for whiteleg shrimp and black tiger shrimp. Globally, black tiger shrimp production tends to fluctuate around 5 billion while whiteleg shrimp production tends to increase. In 2018, seed production reached 29 billion.

In 2015, production decreased compared to 2014. This phenomenon can be explained by the high dependency of breeding producers on the commercial shrimp price. The commercial shrimp price strongly decreased between June 2015 and December 2015. Producers were reluctant to produce shrimp, as the price did not guarantee profits. Hence, the demand for seeds also diminished.

The stagnation in black tiger shrimp seed production is explained by the strong tendency of farmers to convert their ponds to whiteleg shrimp production, reducing the demand for black tiger seed.

4.7.3 Advantages of the province for larval production

Interviews with hatchery owners highlighted some of the production characteristics. These are highlighted in this section.

Why Ninh Thuan?

- It was a government decision to select this area as an area for larval production following the success of the first larval producers.
- Sea water quality
- Stable salinity
- Adequate temperature
- Short rainy season
- The structure of marine currents in the province: A cold current flowing up the coast allows sediment to rise and ensures good water quality. A large number of marine species breed in the region thanks to the ideal conditions developed by these currents. The presence of coral is also an indicator of water quality in the region.

4.7.4 Analysis

4.7.4.1 Broodstock

In Vietnam, hatcheries import broodstock from other countries such as the United States, Thailand, Indonesia, or Singapore, which makes the country dependent on other countries. Moreover, it makes production costs more important than if broodstock were produced locally.

The only hatchery in Vietnam licenced to operate a breeding and genetic programme is Viet-Uc, which is a wholly foreign invested firm. The company has the capacity to produce between 15 billion and 40 billion post-larvae per year and is still building new facilities. Viet-Uc accounted for 24% of the domestic market of shrimp products in 2018. The company has produced its own broodstock since November 2017. (Dao, 2019)

4.7.4.2 *Hatchery process*

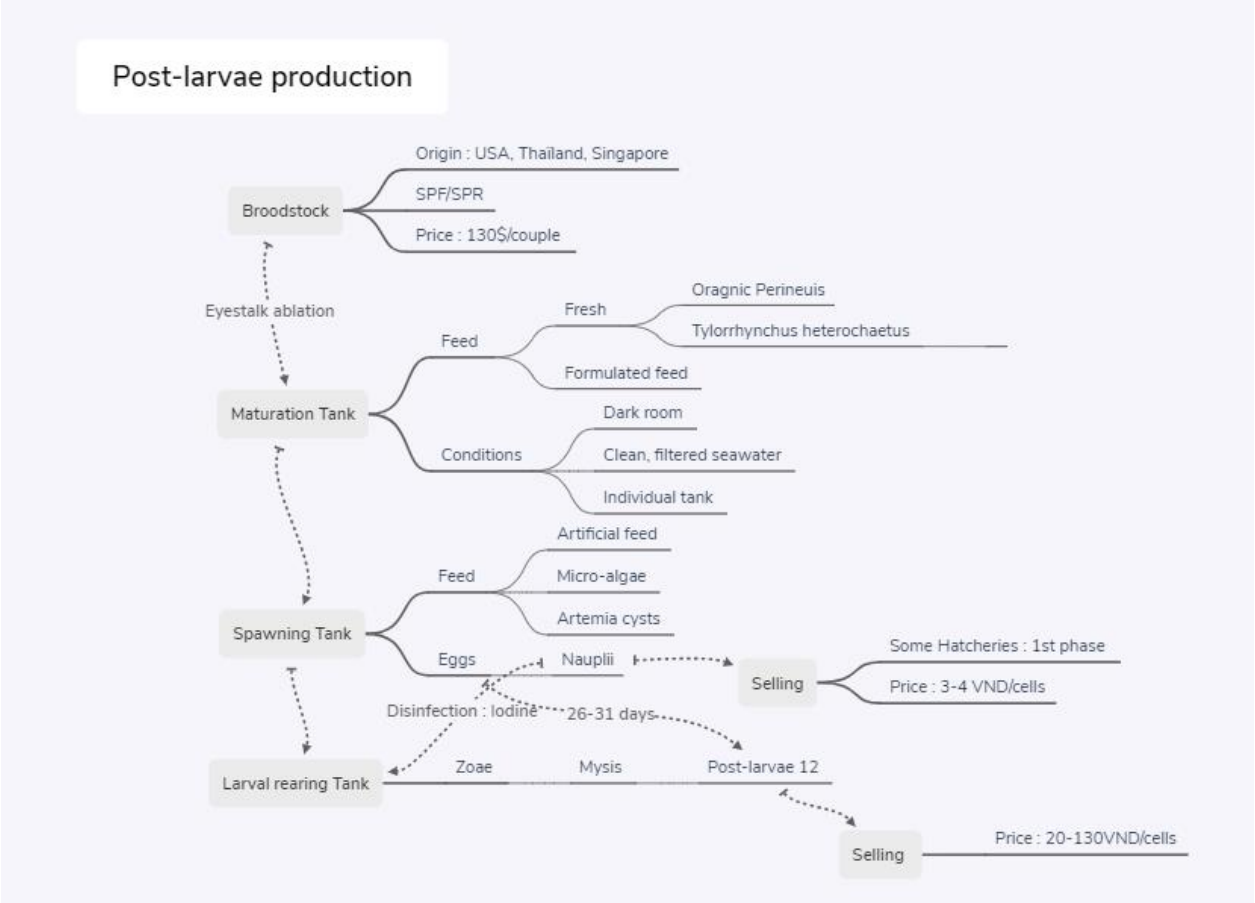


Figure 20: Synthesis of post-larvae production in Ninh Thuan

All the hatcheries interviewed purchase their broodstock from foreign countries such as the United States, Thailand, or Singapore. The price for a male–female couple is around VND 130. The couple is exploited for three to four months. Breeders are imported for genetic quality following selection programmes. These breeders are either SPF or SPR shrimp. These shrimp have undergone a rigorous disease testing and quarantine process before they are declared free of the specified pathogens. They can thus be sold as SPF shrimp. Specific pathogen-resistant shrimp are shrimp that by genetic selection have higher resistance to a specified pathogen. (Briggs, Funge-Smith, & P. Subasinghe, 2005)

Females will have their eyestalk ablated to increase the spawning frequency. Broodstock are then placed in a maturation tank. They are placed in ideal conditions: a dark room, sea water that is treated several times before being put in the tank, and placement in individual tanks to prevent the spread of disease. Their food varies according to the hatchery. Generally, the feed is fresh and sometimes formulated. Fresh food includes species such as *Tylorrhynchus heterochaetus*.

Before spawning, the females are taken to a spawning pond where eggs are laid. The eggs will then hatch. This is the first larval stage called nauplii. The use of light will attract the larvae

and allow them to be collected. Some facilities buy larvae at this stage from hatcheries at a price of 3–4 VND/cell.

The larvae are placed in a larval rearing tank. The feed varies according to the larval stages but is mainly composed of microalgae, Artemia cysts, and artificial feed. The transition from the nauplii stage to the final post-larvae 12 stage takes about 26 days. During this period, disinfection, chlorination, use of antibiotics or probiotics, and water filtration limit pathogen contamination. At the post-larvae 12 stage, the shrimp are sold at a price around 20 to 130 VND/cell. The price depends on the size of the hatchery and its reputation. In Ninh Thuan, most of the stock is sold in the Mekong Delta through a transport company that charges a price per cell.

4.7.4.3 Challenges

1. There is a large distance between shrimp producers and post-larvae producers. The majority of shrimp production is located in the Mekong Delta. From Ninh Thuan, the route is 600 km long and takes 12 hours.

2. When the price of shrimp is low, demand is lower. In response, hatcheries tend to diversify by producing snails, lobsters, etc. Current legislation on snail or lobster larvae is less binding than on shrimp larvae. According to some hatcheries, the increase in the production of snails or lobsters coincided with an increase in the frequency of diseases. There is less disease verification. Larvae thrown into the sea can be a vector of disease.

3. Producers still directly discharge their wastewater and larvae into the outside environment or in coastal water. This practice increases the risk of disease outbreaks and pollutes coastal water. This in turn reduces water quality.

5 METHODOLOGY

5.1 SITE SELECTION

The aim of this study is to describe the aquaculture sector in the Ninh Thuan Province with a focus on shrimp farming.

Shrimp farming is concentrated in two main culture areas:

5.1.1 Naï Lagoon

Naï Lagoon is a coastal bay located in Ninh Hải District, which covers an area of approximately 700 ha. Annual rainfall is usually around 700 to 800 mm with 70% of the rainfall that occurs during the wet season between August and November (Boi, 2001). The wet season regularly causes flooding and makes production impossible during this period for a wide range of producers. The area of commercial shrimp farming in 2017 was around 922 ha. Ninh Hải District with an area of 515.8 ha is the largest production site in terms of surface area.

5.1.2 Production in non-tidal areas

The second culture area is on sandy terrain. Sandy farms are generally concentrated in areas where the government has made investments, such as An Haï (invested in from 2001 up to now) or Son Hai (invested in from 1999 to 2012).

To obtain samples representing the aquaculture situation in the province, two study sites were selected based on their geography and current shrimp production: the first in Phuong Haï (located in Ninh Hải District) to represent the situation in the Naï lagoon and the second in An Haï (located in Ninh Phước District) to represent production in non-tidal areas.

For each location, 15 farmers were randomly selected and interviewed to determine the profitability of the farms and highlight the advantages and shortcomings of each of these locations.

5.2 DISTRICTS: DESCRIPTION

Our study was conducted in two districts: Ninh Phước and Ninh Hải. Their surface areas are respectively 341.95 km² and 253.58 km². Ninh Phước District has the largest population with an average population of 132,400 people and a population density of 387.19 people/km², while Ninh Hải District has a population of 93,720 people with a density of 369.59 people/km². The population density of these two districts is higher than the national average of 283 people/km².

These are the two most densely populated districts after the provincial city of Phan Rang–Tháp Chàm. These two districts are still rural with an urban population of 25,453 people for Ninh Phước (which represents 19.22%) and an urban population of 16,399 for Ninh Hải (17.5%).

5.3 COMMUNE: OVERVIEW

5.3.1 Phuong Haï

Phuong Haï commune is located in the north of Ninh Hải District. The commune has a total natural land area of approximately 1,097 ha and has three villages (Phuong cuu 1, Phuong cuu 2, and Phuong cuu 3). The population of the commune was 6,945 people in 2011, with 4,900 people of working age. A total of 86.6% of the labour force was working in agricultural labour in 2011, while 8.7% was working in the fields of handcrafts and construction, and 4.7% in the field of trade services.

We can thus highlight in advance the importance of the aquaculture and agricultural sector in this commune. Agricultural land in Phuong Haï represents 839.19 ha, of which aquaculture land is 187 ha, accounting for 22% of the total agricultural land and 17% of the total natural land area (1,097 ha) of the commune.

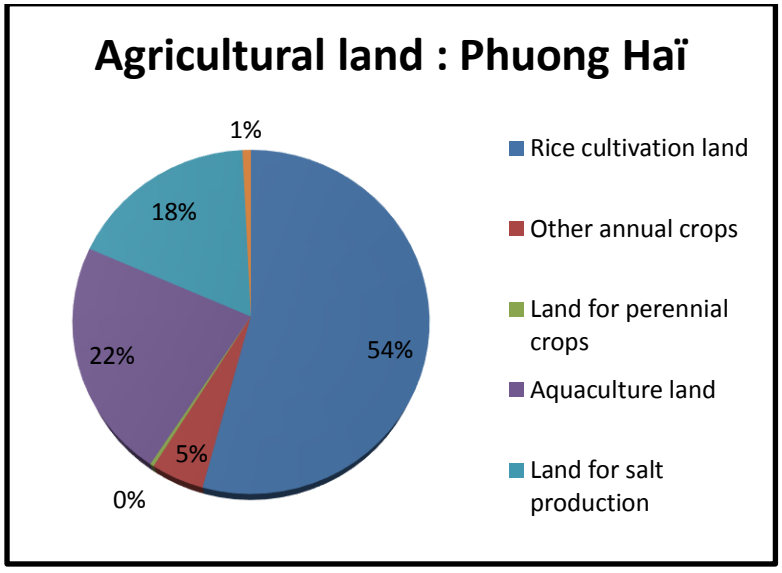


Figure 21: Structure of the agricultural land in the Phuong Haï commune

5.3.2 An Haï

An Haï is located in the south of Ninh Phước District. The population of An Haï was 13,945 people in 2017, with an average population density of around 642.66 people/m², which is a high density compared to the provincial average density. The commune has a total area of

approximately 2,169.88 ha including 1,438.87 ha of agricultural land, of which aquaculture land is 340.19 ha, accounting for 23.6% of the total agricultural land of the An Haï commune.

5.4 QUESTIONNAIRE

The questionnaire used to interview the farmers was written based on the questionnaire written by Ms. Ho Thi Minh Hop during her doctoral thesis: *Integration of Farmers in the Shrimp Subsector in the Mekong River Delta, Vietnam*. The questions were based on the objective of defining the profitability of the farms studied and highlighting the challenges related to the locations studied. Information was obtained from questions relating to the economy, environment, technology, and society.

5.5 FARM SELECTION

The objective of the survey was to determine the profitability of the shrimp sector in Ninh Thuan Province. Thus, farmers were chosen to best represent this sector.

Limitations were encountered during the investigations. We had not obtained a list of farmers in the province, and we had not received the necessary authorisations at the district level to be accompanied by a member of the district aquaculture department. As a result, farmers were selected based on their geographical location.

5.6 DATA COLLECTION

Primary and secondary data were collected through a survey from March 2019 to May 2019. The economic data collected relate to the production period equivalent to 2018. The aims of the survey were to study the profitability of shrimp production and address the challenges of commercial shrimp farming in Ninh Thuan.

Twenty-nine interviews were conducted with farmers in the province in two districts (Ninh Phước and Ninh Hải). Interviews were also conducted with various members of the supply chain such as drug and food vendors and hatcheries. Finally, interviews with politicians, such as members of the aquaculture department, the department responsible for irrigation, the director of the seed-breeding centre and members of the department of sciences and technology provided relevant information on aquaculture in the province. The data was supplemented by secondary data such as annual reports, archives, journals, statistical agency, and newspapers. The Minitab statistical software has been used for the production of statistical tables and graphs.

6 RESULTS

6.1 FARMS: CHARACTERISTICS

This section aims to describe social and physical characteristics of the farms of the farmers interviewed.

Concerning Phuong Haï farms, the average householder age was around 46 ±9 years old. The average farm size was 1,033 ±0.572 ha, with an average of 2.07 ±1.44 production ponds. The number of workers per farm outside the family labour force was 0.833 ±0.947 workers. The year of starting cultivation was around 14 years ago.

Concerning An Haï farms, the average householder age was around 43.53 ±8.13 years old. The average farm size was 0.836 ±0.491 ha, with an average of 4.53 ±3.04 production ponds. The significant difference in the average number of ponds can be explained by the absence of a sedimentation pond for most An Haï producers, which allows them to have more production ponds. The number of workers per farm outside the family labour force was 1.8 ±1.146 workers. The year of starting cultivation was around 4.5 years ago.

6.2 STOCKING DENSITY

One of the most important parameters in shrimp cultivation influencing all stages of production is the stocking density. It can be defined as the number of post-larvae per square metre. The choice of density is specific to each farmer and can vary greatly depending on production techniques and the farmer's experience.

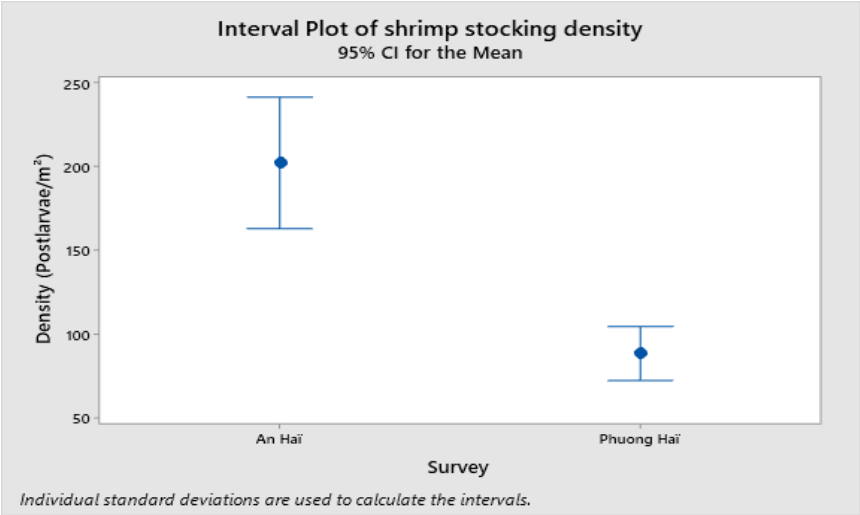


Figure 22: Interval plot of shrimp stocking density (post-larvae/m²)

The stocking density influences the production. A high density can lead to high yields but generates higher production costs and therefore more risks for the producer. Disease, waste management, and feed dosing must be managed precisely at a high density. Otherwise, there can be dramatic consequences for production and losses for farmers.

Figure 22 is a graphic representation of the interval plot of the shrimp stocking density of whiteleg shrimp in both communes studied, An Haï and Phuong Haï.

T-Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
5.77	18	0.000

Descriptive Statistics

Survey	N	Mean	StDev	SE Mean
An Haï	15	201.7	70.6	18
Phuong Haï	14	88.2	27.8	7.4

Figure 23 Statistics of the stocking density for the two communes studied

A t-test reveals a highly significant difference between the two communes, with a p-value lower than 0.000. The average stocking density in Phuong Haï is 88.2 ±27.8 post-larvae per square metre, while it is around 201.7 ±70.6 post-larvae per square metre in the An Haï commune.

In Phuong Haï, many farmers have experienced significant losses in recent years due to shrimp production. But a successful year can generate very significant benefits. That is why farmers continue to produce shrimp, if only by reducing their stocking density to reduce costs. In recent years, those farmers who have produced at a lower density have been more successful. This strategy has since been followed by the other farmers. As a result, a significant difference in density can be observed between the two municipalities, which can be explained by the different natural conditions.

6.3 CULTIVATION DURATION

The shrimp cultivation duration is the same for both areas studied. Indeed, a t-test with a p-value of 0.585 does not reject the null hypothesis (equality of means). The cultivation duration fluctuates around 90 days of cultivation. This is the ideal duration for production, but the crop often varies with natural conditions.

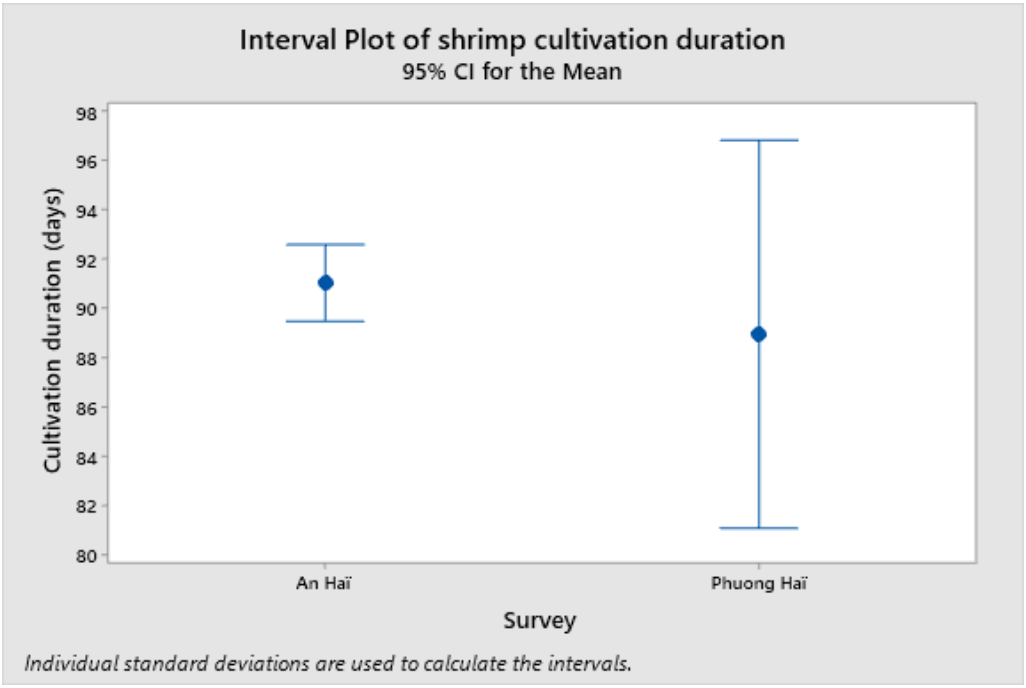


Figure 24: Interval plot of shrimp cultivation duration

Several phenomena can explain a shorter or longer cultivation time depending on the case:

- The appearance of diseases such as AHPND or white spot disease can lead farmers to harvest more quickly to avoid greater losses.
- Some farmers also explained that some production stopped growing and no longer fed (anorexia). To avoid economic losses, they harvested production more quickly.

The cultivation duration of whiteleg shrimp is shorter than that of black tiger shrimp. This makes whiteleg shrimp more suitable for intensive production.

Only three of the 29 farmers interviewed produced black tiger shrimp. Among these farmers, the cultivation of this species was implemented as a second production. The first production was dedicated to the production of whiteleg shrimp, which has a higher yield. In addition, whiteleg shrimp must be harvested at one time, while black tiger shrimp can be harvested gradually. The progressive harvest of black tiger shrimp allowed farmers to harvest until flood season. The cultivation duration of black tiger shrimp is around 100 to 130 days.

6.4 ORIGIN OF LAND

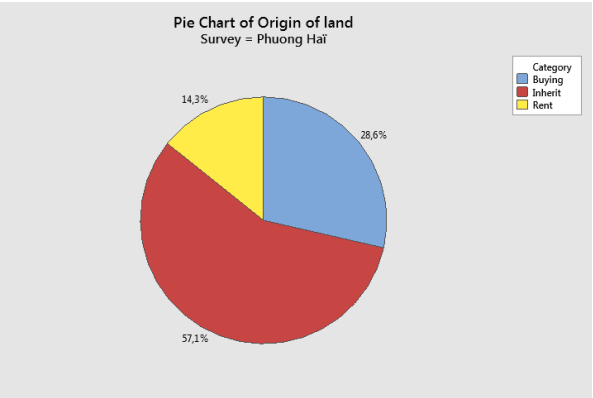


Figure 25: Origin of land in the Phuong Haï commune

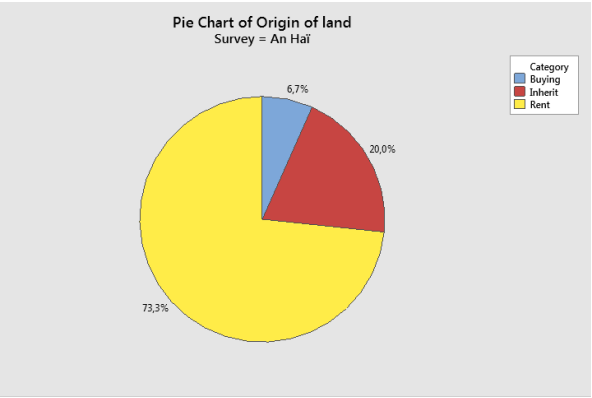


Figure 26: Origin of land in the An Haï commune

The analysis of the origin of the land dedicated to aquaculture clearly reveals the difference between the two communes studied. The area dedicated to aquaculture in An Haï is the result of an aquaculture zone project invested in by the state since 2001, with a total area of 648 ha, of which 282 ha are for aquaculture ponds and 120 ha for aquatic breeding. As part of this project, a water supply system, drainage system, roads, and other infrastructure were built. This area of production is therefore relatively recent and has been implemented in an isolated location, which explains the proportion of farmers who rent their land (73.2%) and the small proportion of farmers who inherited their land (20%). Moreover, 6.7% of the respondents in An Haï had bought their land.

During the period of 2014 to 2015 and before, a large number of farmers had significant losses due to disease and drought. Meanwhile, the rental price of land in An Haï is very high because the government is preventing the increase of aquaculture land in this area. The average rental price per hectare is 142 ±48 million VND/ha per year according to responses to the survey. Farmers who have suffered losses, rather than risk losing even more, have preferred to rent their land. This explains the number of farmers who rent their land.

The graph below presents the year of starting cultivation for An Haï farmers. This confirms the trend. Many of the current farmers started in 2014 or 2015.

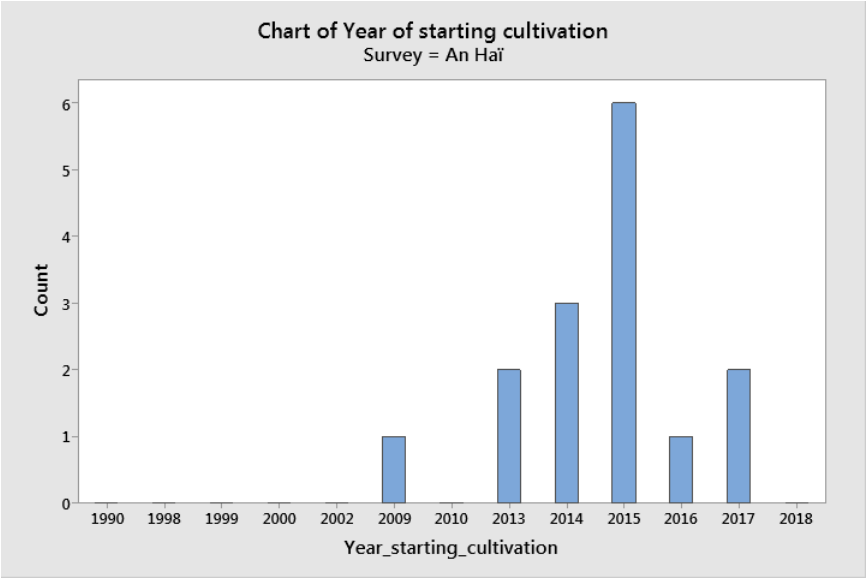


Figure 27: Chart of the year of starting cultivation for An Haï farmers

The commune of Phuong Haï is located on the edge of the Naï Lagoon. The population has developed around this lagoon. The origin of the land is therefore different. Figure 27 shows that 64.3% of the aquaculture land is inherited, 14.3% is rented, and 21.4% is bought. This demonstrates the more traditional aspect of aquaculture in Phuong Haï, in comparison with An Haï. The graph below presents the year of starting cultivation for Phuong Haï farmers. There is a clear difference with the year of starting cultivation graph for An Haï farmers. The starting years for Phuong Haï farmers are more staggered in time.

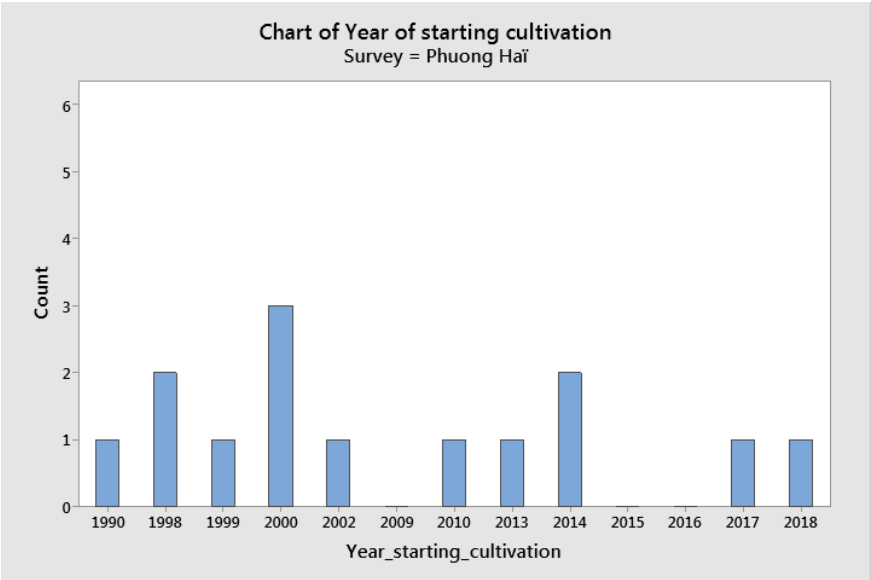


Figure 28: Chart of the year of starting cultivation for Phuong Haï farmers

6.5 AVERAGE SIZE OF PONDS

A t-test concerning the average size of production ponds in Phuong Haï and An Haï reveals that there is no significant statistical size variance between these two locations with a p-value of 0.06, but we can highlight the low p-value, which is very close to the rejection value (0.05) of the equal means hypothesis.

T-Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.98	22	0.060

Descriptive Statistics

Survey	N	Mean	StDev	SE Mean
An Haï	15	0.2029	0.0963	0.025
Phuong Haï	14	0.295	0.147	0.039

Figure 29 Statistics of the average size of ponds for the two communes studied

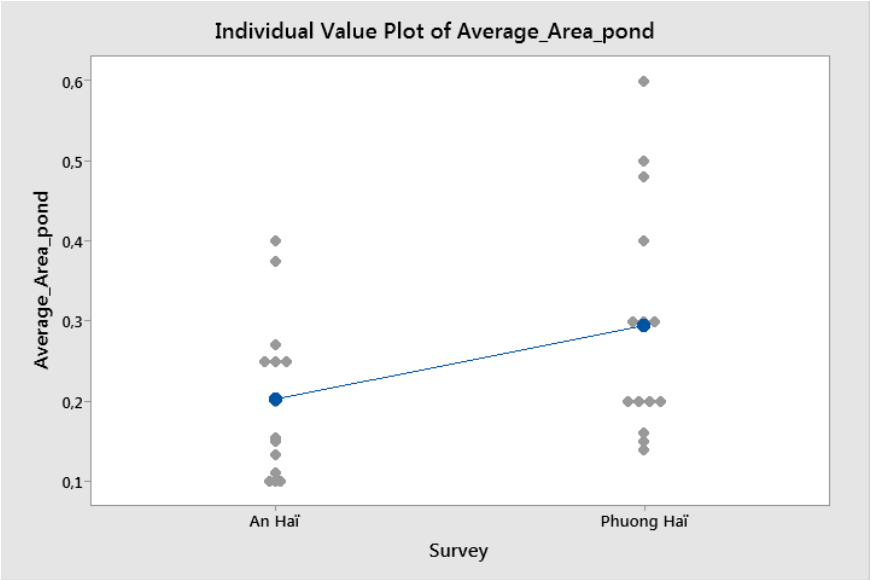


Figure 30: Individual value plot of the average size of ponds (hectares)

Figure 30 illustrates the average size of the production ponds. The average size of production ponds in Phuong Haï is 0.295 ±0.147 ha, while it is around 0.2029 ±0.0963 ha in An Haï. The small size of production ponds in An Haï can be explained by the willingness of farmers to produce intensively and the location, which is less limited by its environment than in Phuong Haï. Moreover, the An Haï producers had started to produce on average 4.5 years ago. The configuration of their farms has been adapted to produce intensively.

6.6 NUMBER OF CROPS

Descriptive Statistics

Survey	N	Mean	StDev	SE Mean
An Haï	15	3.000	0.327	0.085
Phuong Haï	14	1.750	0.643	0.17

T-Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.53	19	0.000

Figure 31 Statistics of the number of crops per year for the two communes studied

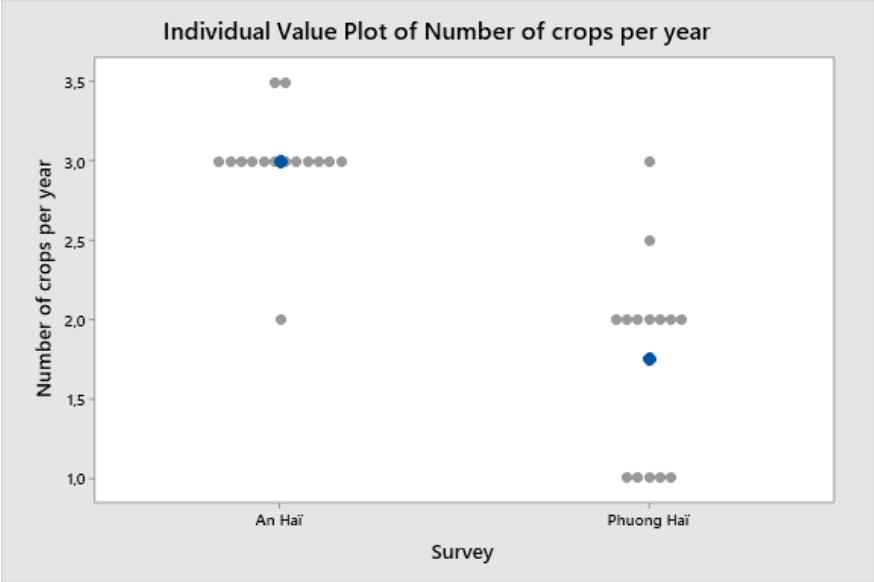


Figure 32: Individual value plot of the number of crops per year

Figure 32 shows the number of crops per year in the An Haï commune and in the Phuong Haï commune. The average number of crops per year is 3 for An Haï, while it is 1.750 in Phuong Haï.

This trend can be explained by the fact that the Phuong Haï commune is located in flooding area: Every year, the production area is flooded during the rainy season. Farmers therefore adapt to the environment by starting production around March to April When the land is no longer flooded and suitable for production. Farmers therefore produce between March and October.

The situation is different in An Haï. Being located in a non-floodable area, farmers produce all year round. They are therefore able to increase the number of crops to three or even four

6.7 YIELD

The yield depends on many factors such as the quality of the post-larvae, the feed, the investment capacity, or the intensity of production. The farmer's experience also plays a

crucial role. Thus, it is interesting to observe farm yields to highlight the success or difficulty of farmers.

Figure 30 reveals an important difference between the Phuong Haï and An Haï communes. The t-test of the average yield of these two locations shows a significant difference between the two locations (t-test < 0.05). As mentioned above, yield depends on a large number of factors.

We have seen in the previous sections the lowest stocking density and pond areas less suitable for intensive production as well as a lower capital capacity in the Phuong Haï commune. These parameters explain the difference between the two municipalities.

Thus, An Haï farmers produce an average of 14,77 ±4,43 tons of shrimp per hectare per crop while Phuong Haï farmers produce around 7.16 ±5.29 tons of shrimp per hectare per crop.

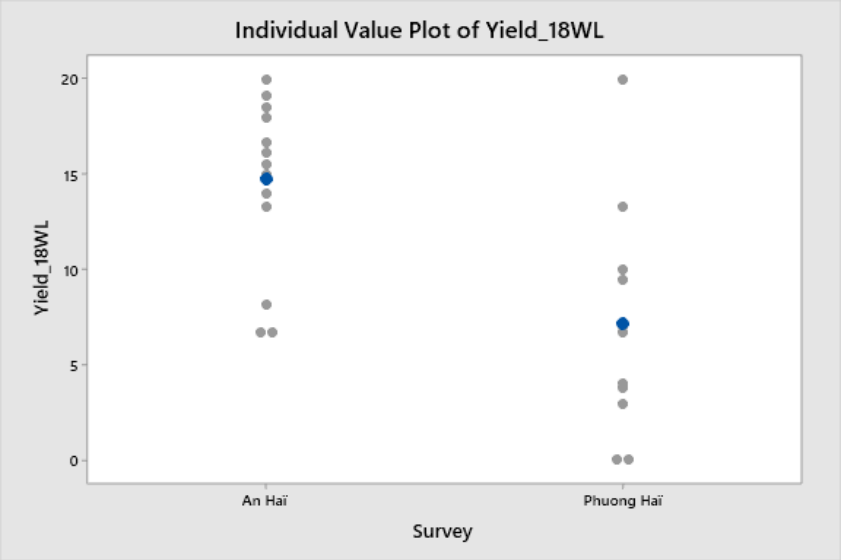


Figure 33: Individual value plot of the yield in tons per hectare per crop

The results for the Phuong Haï commune reveal a wide variation in yield depending on the farms. The average yield is 7.16 tons per hectare, but the standard deviation is important, with a value of 5.29. These large yield gaps show the risks associated with shrimp production. A farmer may have good yields in one year but lose all his or her production the following year.

Concerning the An Haï commune, yields are high in comparison with Phuong Haï, with an average yield of 14.77 ±4,43 tons per hectare. The individual value plot in figure 30 shows a greater homogeneity of yield compared to Phuong Haï. Moreover, there are only three farms with a yield lower than 10 tons per hectare.

6.8 COST STRUCTURE

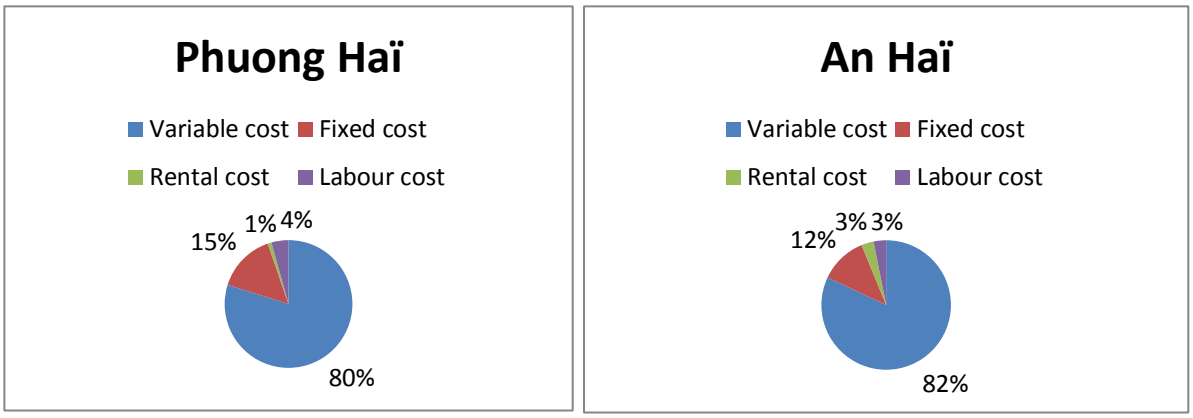


Figure 34: Distribution of total costs in Phuong Haï and An Haï

This section highlights the production cost structure associated with shrimp cultivation. Total cost is composed of variable costs, fixed costs, the price of hired labour, and the land rental price.

The survey results demonstrate that variable costs are the most important cost in shrimp farming. For the two municipalities studied, this cost represents a major part, about 80%, of the production costs. Fixed costs represent 12% to 15% of the total cost, the hired labour represents 3% to 4%, and the land rental price is about 1% for the Phuong Haï commune and 3% for the An Haï commune.

These results show the importance of variable costs in the production cost structure. These significant variable costs imply a very high capital requirement, especially during the last month of production, when shrimp must be fed significantly every day. This need for capital implies that farmers have a constant source of capital. Either the farmer has capital or the farmer has to borrow from the bank or ask for a payment term.

The survey highlighted the reluctance of banks to provide loans to farmers, especially in the commune of Phuong Haï, where shrimp production is seen as too risky by lenders. Therefore, farmers who do not have sufficient capital make an arrangement with the company or the store that sells the feed, medicine, etc., which are paid for after the harvest at an interest rate.

6.9 VARIABLE COSTS

Figure 35: Variable cost structure (percent) of the two communes studied

Cultivated shrimp variable costs include feedstuff, chemicals, post-larvae, and electricity. As mentioned above, these costs represent the largest part of production costs.

Figure 35 presents the structure of the variable costs and the percent of each cost. Overall, the variable cost structure is essentially the same for both communes.

In the Phuong Haï commune, the feedstuff cost represents 55% of the variable costs, medicine/chemicals represent 24%, post-larvae represent 12%, and electricity is 9% of the variable costs. In the An Haï commune, the feedstuff cost represents 52% of the variable costs, medicine/chemicals represent 24%, post-larvae presents 17% and the electricity is 7% of the variable costs.

Unit: Millions of VND/Hectare	Phuong Haï	An Haï
Chemical	53.53 ±17.27	914.27 ±86.97
Post-larvae	62.34 ±16.38	672.68 ±72.44
Feedstuff	206.41 ±31.34	1,983.19 ±163.80
Electricity	31.18 ±2.74	254.89 ±33.44
Total	353.46 ±58.73	3,825.02 ±276.67

Figure 36: Variable cost structure (millions of VND/ha)

Figure 36 presents the variable cost structure of the two communes surveyed in millions of VND per hectare. Overall, we can highlight the very significant difference in the scale of costs.

In the An Haï commune, the average variable costs are VND 3,825.02 ±276.67 million, while the average variable costs are VND 353.46 ±58.73 million in Phuong Haï, which is more than 10 times lower.

This difference is explained by several parameters:

- Variable costs are defined on the scale of the production year 2018. However, the number of crops grown per year is different for the two places. It is 1.75 for Phuong Haï and it is 3 on average for the commune of An Haï. More crops mean more costs, but that cannot entirely explain the difference in variable costs.
- The difference of stocking density: In a previous section, the high stocking density of An Haï producers was highlighted. Figure 37 below shows the price paid by producers for post-larvae. Overall, the highest price paid by An Haï producers can be highlighted with an average cost of 109 VND/cell, while it is around 68 VND/cell in the Phuong Haï commune. Thus, producers in An Haï grow more larvae per hectare and buy them at a higher price.

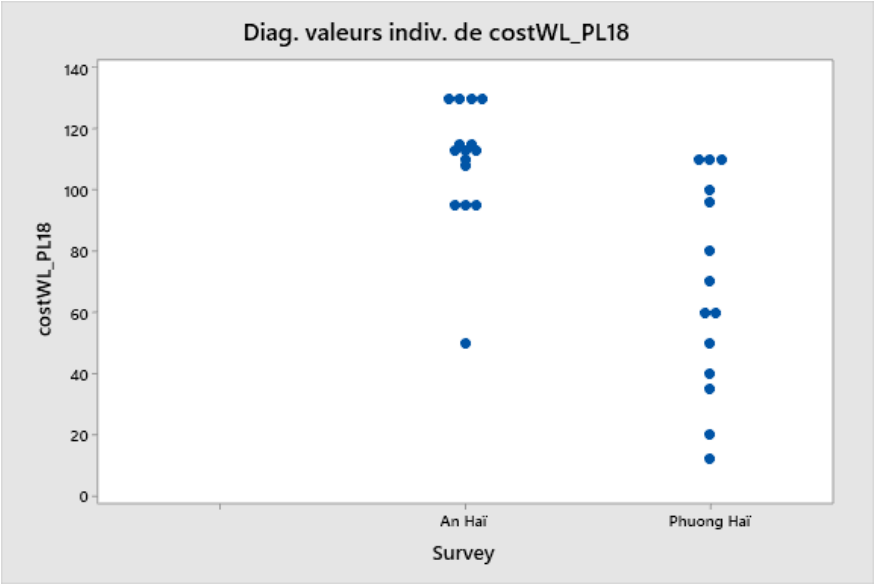


Figure 37: Price paid by farmers for post-larvae per cell

- The higher electricity consumption is due to the need to aerate the ponds to avoid any lack of oxygen. A higher stocking density implies a more efficient ventilation system.

- Costs related to chemicals can be explained by:

    - The higher stocking density
    - Sedimentation pond: There is an absence of a sedimentation pond on a large number of farms in An Haï, while in Phuong Haï, all farms have a sedimentation pond. This pond is used to treat water using natural processes before using the water in the cultivation process. In An Haï, with the land rental price being high, producers prefer to use the space for production. But the

absence of a sedimentation basin implies more important treatments are needed and therefore higher costs related to chemicals are incurred.

- Earlier harvesting: Variable costs are the most important during the last month of production. Feedstuff takes up the largest part of the variable costs. In the last month, with the exponential growth of the shrimp, the need for feed is very high, which is correlated with the high capital requirement in the last month of production. However, during the period studied, 2018, the trend towards early harvesting was strong in the Phuong Haï commune. As the shrimp were sick or no longer feeding, the producers harvested before the theoretical end of cultivation. Thus, expenses were lower for a large proportion of Phuong Haï producers because of the earlier harvesting.

6.10 FIXED COSTS

The fixed costs in this survey include the costs related to the preparation of the pond before cultivation and the depreciation costs related to investments.

	Pond preparation costs		**Depreciation costs**	
	Value (millions of VND/hectare)	Percentage of fixed costs	Value (millions of VND/hectare)	Percentage of fixed costs
Phuong Haï	38.58 ±58.89	59%	27.30 ±24.35	41%
An Haï	380.14 ±239.10	61%	171.39 ±73.70	31%

Figure 38 Fixed cost structure in the Phuong Haï and An Haï communes

Figure 38 shows the fixed cost structure in both communes. First, it is important to mention the significant standard deviation for fixed cost values. This is due to the difference between the farms studied but also to the small sample studied.

The same trend as for variable costs can be highlighted: Fixed costs are nearly 10 times higher in the commune of An Haï than in Phuong Haï. This demonstrates that An Haï farms have made larger investments and need more capital to prepare for production. This can be explained by the very intensive production in An Haï, which requires more equipment. The larger number of ponds per hectare, as mentioned in a previous section, may also explain this difference.

6.11 UNIT COSTS

Statistics

Variable	Survey	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
cost_prodkg	An Haï	15	0	114030	5456	21129	91579	100986	102504	132213
	Phuong Haï	13	1	91727	11019	39729	52232	58700	86760	105184

Variable	Survey	Maximum
cost_prodkg	An Haï	161728
	Phuong Haï	192093

Figure 39 Statistics of the cost of production for the two communes studied

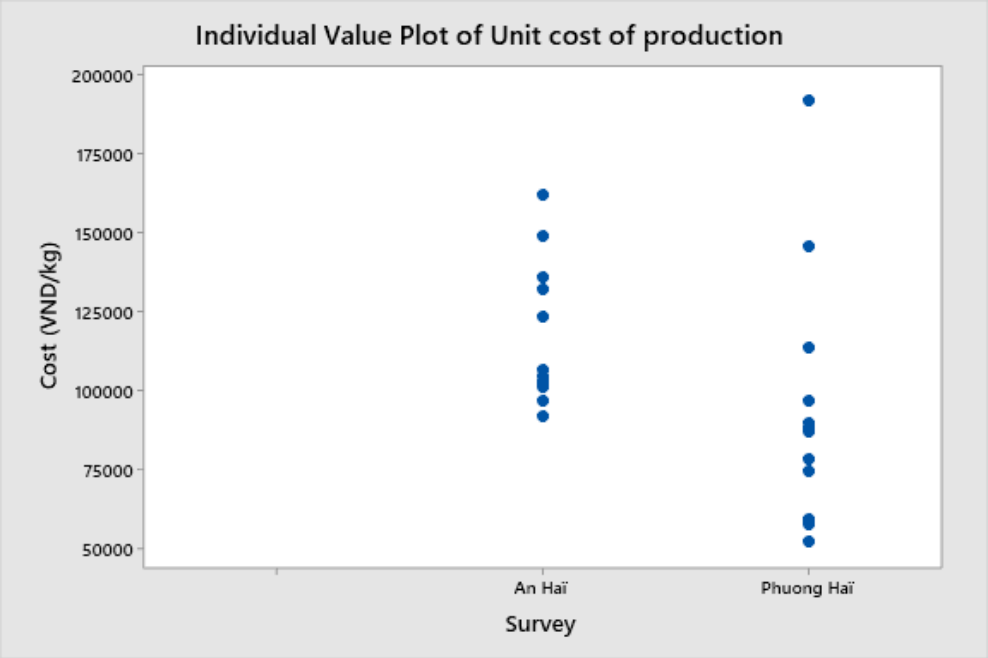


Figure 40: Individual value plot of the unit cost of production

The unit cost of production is defined as the total expenditure incurred by a farm to produce 1 kg of shrimp. The formula for calculating this cost is as follows:

$$Unit\ cost\ \left(\frac{VND}{Kg}\right) = \frac{Variable\ costs + Fixed\ costs}{total\ production}$$

Figure 40, which is a individual value plot, shows the unit cost for each farm. The average unit cost for the An Haï commune is around 114,030 ±21,129 VND/kg, while it is around 91,727 ±39,729 VND/kg for the Phuong Haï commune.

The production cost is thus higher for the commune of An Haï. This makes sense given the higher production intensity. A higher storage density means more treatment and costs to

maintain good water quality. This also highlights the risk associated with shrimp production. As production costs are high, good performance is essential to reduce them.

The cost of production is close to the selling price. Producers in An Haï benefit from their large production to be able to sell their shrimp at a good price, which allows them to be profitable. But they are more likely to be affected by shrimp market price fluctuations.

Concerning the Phuong Haï commune, the unit cost fluctuates around VND 91,000 but there are only three farms whose unit cost is higher than 100,000 VND/kg. The median is 86,760 VND/kg. Despite a lower yield, lower investment and lower stocking density allow farmers to produce at a lower cost. The very high values observed are due to farms with very low yields. This is due to diseases, pollution, etc.

There are four farms, out of the 14 studied in the Phuong Haï commune, with a unit production cost lower than 60,000 VND/kg. This low production cost can be explained by the tendency of the commune's producers to move towards a more extensive system. According to the survey, farmers have suffered heavy losses in recent years. The reaction was either to produce other species or to reduce production intensity. The decrease in intensity allows producers to commit less capital to shrimp production. If yields are good, they generate significant income with a lower cost of production, which is the case for these farms.

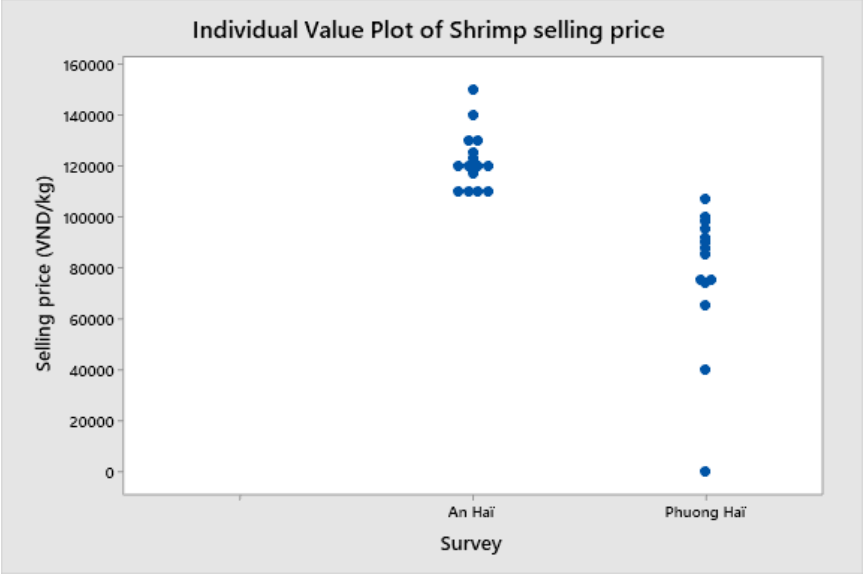


Figure 41: Individual value plot of the shrimp selling price by farmers

The individual value plot of the shrimp selling price in figure 41 illustrates by one point the selling price for each farm studied. A significant difference in shrimp selling prices between the two communes is clear. A t-test confirms this difference with a p-value smaller than 0.05 as shown on the figure below. The average shrimp selling price is 122,363 ±11,539 VND/kg in An Haï, while it is around 77,361 ±28,015 VND/kg in Phuong Haï.

T-test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
5.58	17	0.000

Statistics

Survey	N	Mean	StDev	SE Mean
An Haï	15	122363	11539	2979
Phuong Haï	14	77361	28015	7487

Figure 42 Statistics of the shrimp selling price for the two communes studied

The difference in the shrimp selling price can be explained by:

1. Farmers in Phuong Haï harvested their shrimp faster than farmers in An Haï. As a result of diseases or a halt in growth, farmers harvested their production more quickly to avoid a total loss. This early harvest implies a smaller size of shrimp. However, the purchase price is directly proportional to the size of the shrimp.
2. The sales force of An Haï producers is large given the large quantity of shrimp produced. This provides An Haï producers a greater ability to negotiate with buyers.
3. The greater confidence that buyers have in An Haï producers.
4. Given the small quantities produced, producers in Phuong Haï generally sell their production in the domestic market.

6.12 GROSS VALUE ADDED AND NET VALUE ADDED

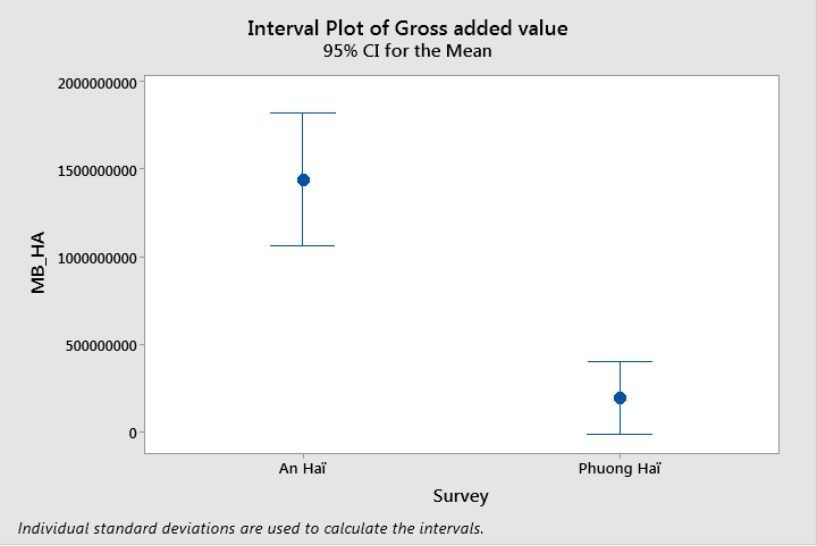


Figure 43: Interval plot of the gross value added for the two communes studied

Gross value added is the value of output less the value of intermediate consumption; it is a measure of the contribution to GDP made by an individual producer, industry, or sector (OECD). By subtracting the consumption of fixed capital from the gross value added, the corresponding net value added is obtained.

Figure 38 shows the average gross value added generated by the farmers interviewed. Overall, we can highlight the higher gross margin generated by farmers in An Haï, with an average gross value added of around VND 1.44 billion. Although their production costs are higher,

their high production yields create significant added value. Concerning the commune of Phuong Haï, 10 farmers out of 13 are at a gross margin between -250 and +250 million VND/ha, with an average of 191 million VND/ha.

Variable	Survey	N	N*	Mean	SE Mean	StDev	Minimum	Q1
NAV_ha	An Haï	15	0	1269942006	168556703	652817304	29660625	738328537
	Phuong Haï	14	0	164608380	90983141	340427742	-183308571	-54190157

Variable	Survey	Median	Q3	Maximum
NAV_ha	An Haï	1181602411	1714778268	2742733268
	Phuong Haï	41124264	320012197	1058774034

Figure 44: Statistics of the net value added for the two communes studied

Figure 43 shows the average net value added generated by farmers in An Haï and Phuong Haï. Concerning the Phuong Haï commune, the average net value added is VND 177 ±48 million. It is interesting to highlight the median of these values. The median of the net value added for this commune is VND 48 million. Thus, 50% of farmers have a lower net value added. Concerning the An Haï commune, the average net value added is VND 944 ±523 million and the median is VND 1.114 billion.

6.13 RETURN TO FAMILY LABOR

Return to family labor is defined as net value added less wages and the rental price of the land. This section aims to describe the final profitability of both communes studied.

Concerning the An Haï commune, figure 40 provides a summary report on the return per hectare for the An Haï commune. Overall, the average return per hectare is very high, with an average of 980 million VND/ha. It is interesting to note that only one farm does not generate return to family labor. This high profitability shows that the production system of An Haï farms is very efficient. Even if, as previously mentioned, the farms remain dependent on a good selling price because production costs are high.

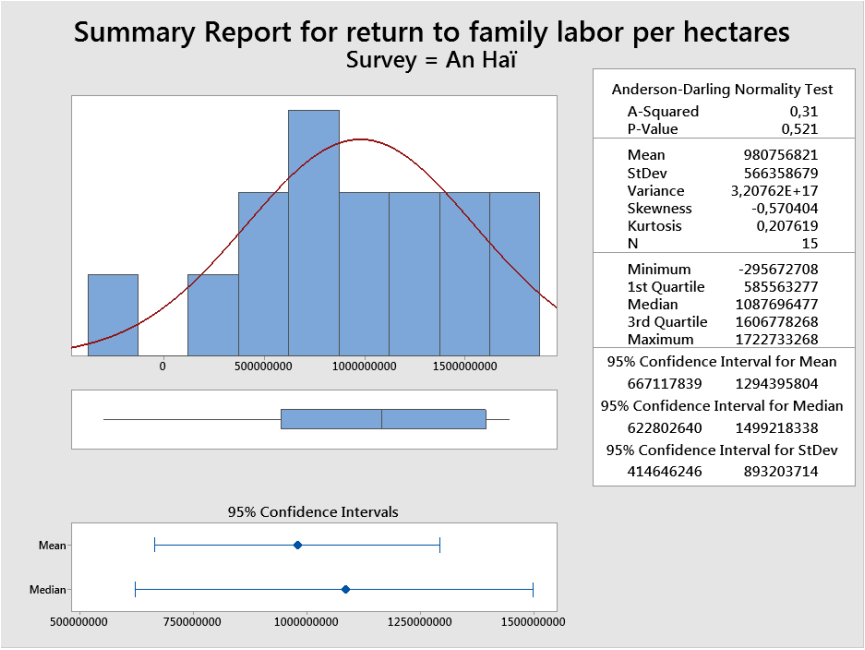


Figure 45: Summary report of the return to family labor per hectare in the An Haï commune

Concerning the Phuong Haï commune, the average return is around 141 ±334 million VND/ha. The standard deviation of the mean is very large. The values are therefore highly dispersed around the average profitability. The small sample size studied may explain this large standard deviation. The median with a value of 20.7 million is very low. Six farms out of the sample of 14 studied have a negative return for the year 2018, which represents 43% of the farmers interviewed. Although the sample is small and the standard deviation is very large, this shows that production in this commune is not efficient.

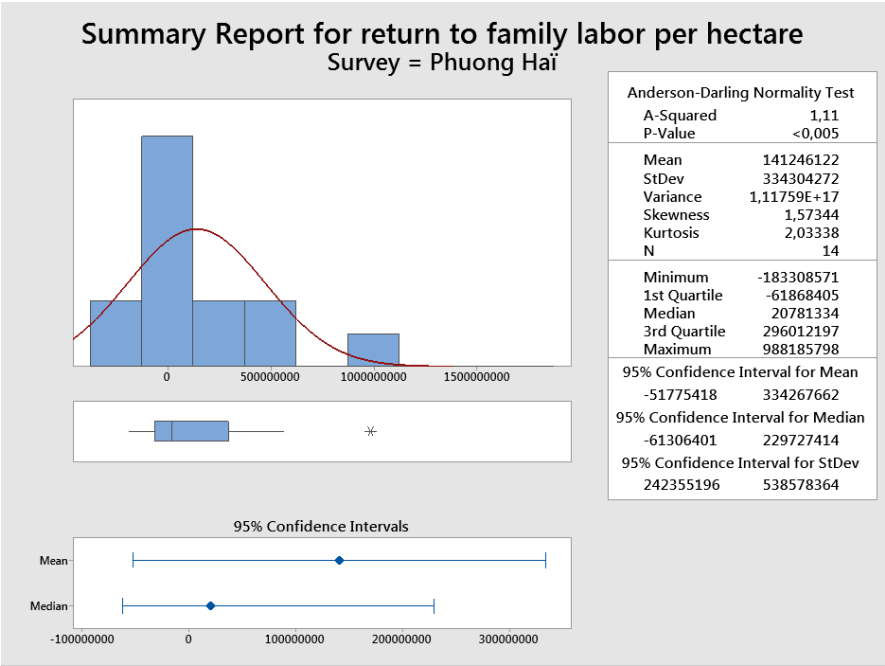


Figure 46: Summary report of the return to family labor per hectare in the Phuong Haï commune

6.14 RESULTS: CONCLUSION

The table below summarises the results obtained for the two communes studied.

To summarise, Phuong Haï shrimp farming can be qualified with low capital requirement, lower intensification, and highly variable economic results. The cost of production is small but the selling price is also, which makes farm profits low. Irrigation problems, disease pressure, poor larval quality, drought, and pollution and salinity issues make production in this area hazardous. According to farmers, many of them tend to do the following:

- Switch to the production of another species such as snails or oysters
- Convert their production ponds to the production of salt, which is less variable and whose sale is guaranteed by a nearby factory
- Produce extensively to avoid losses. Some farmers produce a whiteleg shrimp crop and then extensively produce black tiger shrimp with crabs until the flood season arrives.

Overall, it can be concluded that shrimp production in Phuong Haï is not profitable and that the trend is towards extensive production farming or changes in production. An Haï shrimp farming can be characterised by an intensified production system, with recent installations and high yields and returns. The cost of production is higher for An Haï shrimp farms, but the production is sold at a more attractive price. As a result, most farms in An Haï are very profitable. As production costs are high, high yields must be obtained. Although profits are important, An Haï farmers are not immune to a rise in the price of food or a fall in the price of shrimp.

As a general conclusion, aquaculture in Ninh Thuan province can be considered as highly diversified. For an effective implementation of the project, it will be important to make a preliminary selection based on the ability of the farms to adopt the proposed technology.

	Unity	**Phuong Haï**	**An Haï**
Stocking density	Postlarvae/m²	88,21±27,82	201,7±70,6
Pond size	Hectare	0,295±0,1467	0,2029±0,0963
Number of crops	Crops/year	1,75±0,643	3±0,32
Cultivation duration	Days	88,93±13,61	91±2,803
Yield	Tons/Hectare	7,16±5,29	14,77±4,43
Shrimp selling price	VND/kg	77361±28015	122363±11539
cost of production	VND/kg	91727±39729	114030±21129

Figure 47: Summary of the main characteristics of farmers in the two communes

7 CHALLENGES

7.1 DAM NAÏ

7.1.1 Lack of an irrigation infrastructure

The irrigation system in the Phuong Haï commune is limited. According to farmers and reports on aquaculture, the irrigation network is composed of a single channel. Farmers pump their water directly from the canal. Wastewater is also discharged into this channel. Thus, there is no differentiation between irrigation and wastewater discharge channels. As the season progresses, the water in the canal becomes more and more polluted. Diseases can spread more quickly from farm to farm through channels. Figure 48 shows the irrigation canal of Phuong Haï. The fresh water from the rice fields comes from the left while the salt water from the lagoon comes from the right. The mixture is thus not homogeneous, and the salinity varies according to the proximity to the rice fields and the lagoon.

Figure 48: Irrigation canal in the Phuong Haï commune

Fresh water comes directly from the irrigation water in the rice fields. There is a risk that these waters may be polluted with phytopharmaceuticals or fertilisers used in rice cultivation. This creates a risk of contamination for shrimp.

The levelling of the channel is not homogeneous. Producers near the freshwater source have low-salinity water. While those near the lagoon have little access to fresh water. Salinity is an important parameter for good production. Recurrent droughts exacerbate this phenomenon, and access to fresh water is becoming increasingly difficult.

As a result of this failed irrigation system, farmers dig wells for fresh water. In the province with the lowest groundwater level in the country, particular attention must be paid to this issue, especially since the quality of the water pumped, according to producers, is also of poor quality. Indeed, this requires pre-production treatments due to the concentration of heavy metals or nitrate.

7.1.2 Flooding

Realisation : André Parent, 2014 – source : Oxfam,2008

Figure 49: Map detailing areas at risk from extreme weather conditions in Vietnam

Figure 49 presents the areas most at risk from climate change in Vietnam. It appears that the coast of Ninh Thuan Province is considered one of the most at-risk areas. The Naï Lagoon is particularly prone to future natural disasters. Indeed, a one-metre storm surge would be enough to cause damage. .(Yann Roche and Pham Van Cu, 2015)(Chaudhry & Ruysschaert, 2008)

7.1.3 Drought

Evapotranspiration in Ninh Thuan Province is one of the highest in the country. Droughts are becoming more frequent, according to farmers. Access to fresh water is also decreasing. As a result, it is becoming increasingly difficult for farmers to maintain a constant level of salinity.(Chaudhry & Ruysschaert, 2008)

7.1.4 Post-larvae quality

The quality of the post-larvae is not homogeneous. Whiteleg shrimp broodstock is mainly imported from different sources. The quality is not stable and the price for quality is high.

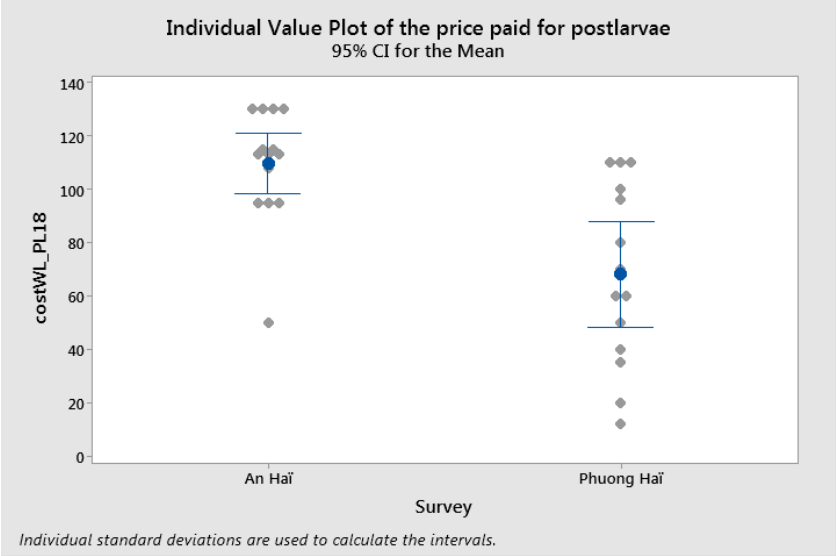


Figure 50: Individual value plot of the price paid by farmers for post-larvae

Figure 50 is a diagram of the individual values of the price paid for post-larvae. This figure shows the diversity of purchase prices.

In An Haï, price diversity is lower. Producers seem to be concerned about the quality of larvae. They buy larvae at a significant price (the average price is 109 VND/cell) and from trusted companies such as Viet-Uc. Indeed, out of the 15 farmers interviewed, 11 of them buy post-larvae from Viet-Uc.

Concerning the commune of Phuong Haï, the average price is 68 VND/cell. The diagram shows us that the price varies enormously among farmers. The minimum paid is VND 12 and the maximum is VND 110. Some farmers neglect the importance of obtaining good quality larvae. Some prefer to save money by buying from a company selling at a low price or buying larvae directly from the market.

All farmers should be aware of the risk of disease and loss due to purchasing poor-quality post-larvae. Therefore, awareness campaigns could be beneficial to producers.

7.1.5 Shrimp selling price

The selling price of shrimp in Phuong Haï is very variable and generally low, as seen on the figure 41, the creation of producer associations with the aim of negotiating better sales prices could be a solution.

As a conclusion to this section highlighting the challenges related to production in Phuong Haï, figure 46 aims to synthesise the main challenges faced by this commune.

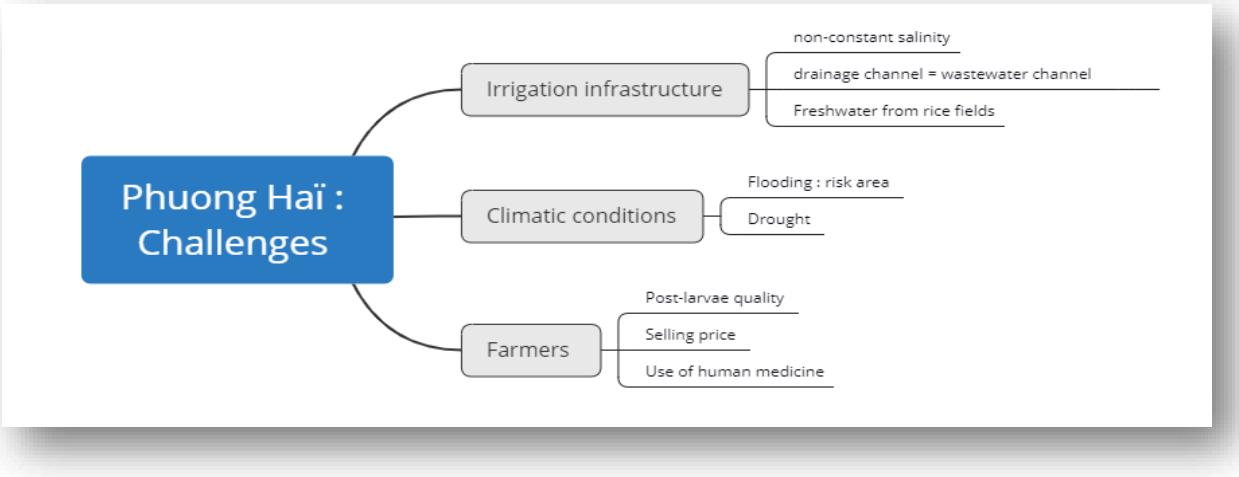


Figure 51: Synthesis of the aquaculture challenges associated with the commune of Phuong Haï

7.1.6 Suggested improvements

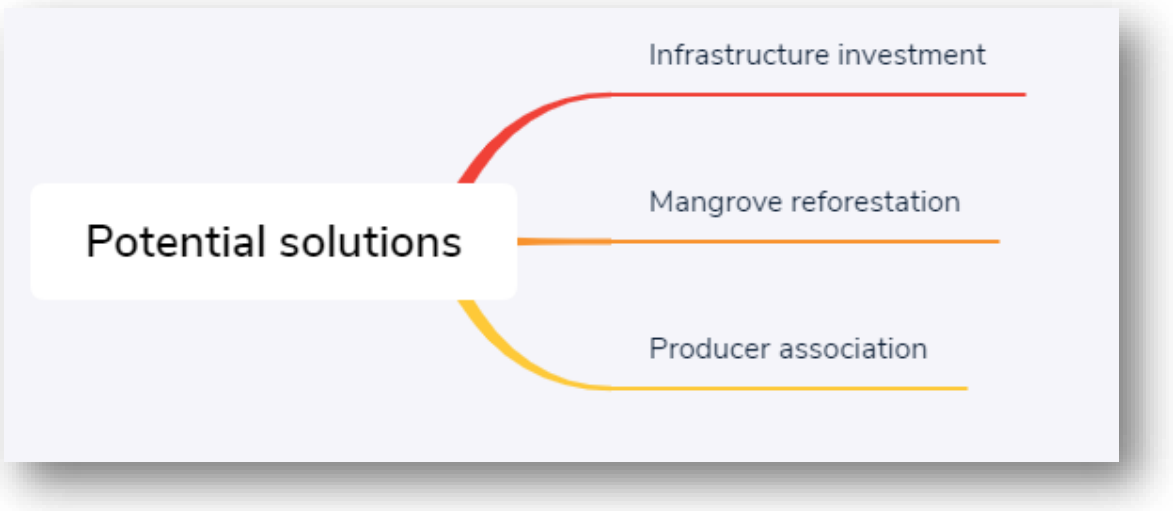


Figure 52: Suggested improvements for the Phuong Haï commune

This section proposes some potential improvements that could benefit the municipality's production.

7.1.6.1 Infrastructure investment

The lack of adequate infrastructure is the main reason for low yields. The mixing of wastewater with clean water leads to more disease, pollution, etc. Investment in this area is essential to make production safer for farmers.

7.1.6.2 Mangrove reforestation

In the 1980s, the area of mangrove forests in the Naï Lagoon was 300 ha, while in 2010 it was estimated at 17 ha. Thus, 95% of the mangroves were destroyed in 30 years. The remaining mangroves are very poorly diversified and are made up of only six different species, while the mangroves in other areas of Vietnam may contain about 40 species (Nguyễn Văn Long, 2009).

This huge decrease is due to many parameters, such as the felling of mangrove for the expansion of residential quarters or for the development of infrastructure, the lack of management, and the construction of ponds for aquaculture. Concerning the Naï Lagoon, the destruction of mangroves to create production ponds is the main reason for this decrease in mangrove species.

Mangrove forests provide many ecosystem services. As mentioned in a previous section, major floods occur every year during the rainy season. According to a number of studies, one of the

services of mangrove forests is to protect the littoral from climate events by acting as a buffer between the shoreline and the tides (Alongi, 2008).

Although mangrove restoration plans have been initiated in recent years, they do not yet consider the area of mangrove forest that has been destroyed in Phuong Haï. Considering the many services that mangroves could provide, it seems of interest to continue the reforestation process.

7.2 AN HAÏ

7.2.1 Irrigation

The irrigation system in An Haï is composed of four pump stations:

- ⇨ Two pump stations that pump water in the Phan-Rang estuary (salinity: 10–20 g/l)
- ⇨ Two saltwater pump stations that are located on the coast of An Haï and pump water from the sea

After the water is pumped, it is sent to the main irrigation channel. Salt water and *fresh water* are mixed together. According to the irrigation department of Ninh Thuan, the irrigation canal is used for only 15 ha of the 428 ha of aquaculture. This phenomenon can be explained by several issues about this infrastructure:

1. Due to past bad experiences with irrigation water, farmers do not trust the water quality.
2. The two saltwater pumps are no longer working. Although the salinity of the water from the estuary is adequate for aquaculture, it is not ideal and the estuary is considered polluted by farmers.
3. Farmers with an area of more than 2 ha of production must participate in the maintenance of the irrigation canal.
4. There is no water monitoring.
5. The canal is very basic: There is only one main canal and no branch facilitating access to this water for farmers. Some producers are located far from the canal, and it is difficult for them to obtain water from the canal.

As a result, producers dig wells for fresh water and pump water from the coastal water. As in Phuong Haï, pumping groundwater could be dangerous since the province has the lowest reserves in the country. Concerning wastewater treatment, the An Haï aquaculture area has a basin to retain water before discharge into the sea, as shown in the picture below.

Figure 53: Picture of the wastewater basin in the An Haï commune

Theoretically, producers are required by law to discharge their wastewater into this basin. In practice, this is not respected and a large number of farmers discharge their wastewater directly into the sea or the outside environment. Moreover, there is a lack of resources to treat the wastewater in the basin. The consequences of this lack of water treatment can be significant, especially for groundwater and coastal-water quality on which producers directly depend.

7.2.2 Water quality

Farmers who have dug wells for water supply report that the water quality is poor. The water extracted would contain a significant concentration of heavy metals, phosphate, and nitrate near the urbanized areas. Farmers must therefore treat this water with chemicals to make it suitable for aquaculture. This implies higher water-treatment costs for producers. But it also raises questions about the quality of the groundwater. In addition, water treatment is difficult for farmers in An Haï. They generally do not have a sedimentation basin. The price of renting land is high, so producers prefer to use the surface area only for production.

8 DISEASE

For both communes studied, diseases are the main cause of economic losses. In recent years, major disease outbreaks such as WSSV or AHPND occurred in the Phuong Haï and An Haï communes. As mentioned in a previous section, diseases are the first source of losses for farmers. The area of diseased shrimp as of 2 November 2018 was 88 ha out of a total area of 952 ha in Ninh Thuan. This represents 9.24% of the total area of the province. Such a disease-impacted area has resulted in production losses of anticipated harvests and therefore lower yields.

The problems identified in the previous sections such as the water quality, the lack of infrastructure, the quality of post-larvae, and the lack of differentiation between irrigation and wastewater discharge channels facilitate the spread of diseases and make disease management inefficient. Disease management is a key issue in the shrimp sector. Management is still too individual and to the detriment of the producer community. Laws exist, but they are not respected. This issue is certainly a key factor in the development of aquaculture in Ninh Thuan Province. Moreover, sustainable aquaculture ties in with good disease management. Good aquaculture practises would create better water quality, improve the irrigation infrastructure, and therefore, reduce disease pressure.

9 GLOBAL ISSUE: DEPENDENCE ON IMPORTS

We saw during the analysis of the unit costs of production that unit costs are high for intensive production and relatively close to the selling price. In addition, variable costs represent the majority of production costs (80%). Feedstuff accounts for more than 50% of these costs, and the cost of medicine accounts for 24%. Thus, the price of feed and pharmaceutical products play a very important role in the economic efficiency of the shrimp production system. However, the majority of feed and pharmaceutical products come from abroad and from foreign companies. The supplying companies come from the United States, EU, Japan, Taiwan, and Singapore. This dependence on imports is one of the greatest weaknesses of the aquaculture industry in Vietnam. It implies a strong correlation between the health of the shrimp sector and the prices of feed or pharmaceutical products. Moreover, most shrimp production is for export. Thus, the sector is also very dependent on the international market price.

Surveys have shown that feed prices have been rising in recent years. Given the importance of these cost parameters, the dependence on imports by the Vietnam's aquaculture sector appears to be a key issue.

10 MAIN OBSTACLES TO SUSTAINABILITY

In the previous sections, the difficulties encountered by farmers have been highlighted. The purpose of this section is to highlight the main obstacles to sustainable aquaculture in Ninh Thuan in accordance with the concept defined above.

10.1 WATER CYCLE

- Aquaculture requires a large amount of water. The production of shrimp in brackish water requires both fresh and salt water. We have seen that irrigation systems in the two locations studied were not effective. Thus, producers dig wells to collect water directly from groundwater. However, groundwater reserves in Ninh Thuan are the lowest in the country.

- The discharge of wastewater directly into the sea or the external environment is practiced in Ninh Thuan. The wastewater basin in An Haï is not efficient, and the wastewater is discharged directly into the irrigation canal in Phuong Haï.

The problem of water management has unsustainable consequences:

- Pollution of groundwater and coastal water
- Risk of groundwater depletion
- Pollution of water for human consumption
- Salinisation

These consequences will likely directly impact shrimp production in the future.

10.2 USE OF MEDICINE

Another issue is the use of drugs in production ponds. During the investigation, the use of human medicine was noted. These drugs are not authorised for aquaculture because they can have significant consequences for the environment as well as lead to pathogen resistance to drugs.

10.3 PRODUCERS

Another obstacle is the will of producers. Although they are aware of the decrease in environmental quality, the main interest of the producer is income in the short term. The consequences related to unsustainability are not direct and it is not natural to fight against something that does not yet exist. In addition, investing in more sustainable aquaculture would result in costs for producers, and the main objective of producers is to be profitable. This is why these investments should come from the state, a law, or they must generate a direct economic interest for producers.

11 COMMENTS ON THE ADOPTION BY FARMERS OF THE NEW PROCESS PROPOSED BY THE RENEWABLE PROJECT

The purpose of this section is to provide a brief analysis of the RENEWABLE project and to highlight the difficulties that the project could encounter during its implementation.

As a reminder, the specific objective of this project consists of demonstrating the feasibility of the reduction of pollution load from aquaculture wastewater discharged into coastal areas by using microalgae and their biomass valuation techniques and to disseminate this technology to farmers.

First, the project is part of a solution to the wastewater problem highlighted during the survey, but it faces certain limitations that it will have to address to be effectively implemented.

One limitation is the need to propose a process that brings added value to farmers. Farmers will not likely turn to microalgae production if it is not economically profitable for them. An Haï farmers who produce intensively do not have a sedimentation basin to optimise the available surface area. In addition, the survey revealed that shrimp production is extremely profitable for them. The process of manufacturing microalgae takes months, which for farmers could be seen as a loss of income. For farmers to implement the process, they will likely need to benefit from it.

If the process has a low direct profitability, it may be appropriate to implement payments for environmental services. This market-based solution, commonly defined as an environmental policy instrument, could be used to fulfil the dual objectives of sustainable aquaculture and economic effectiveness. Farmers would receive a compensation for wastewater treatment, for example. This compensation could take many forms such as cash, in-kind assistance, exemption from taxes, tenure security, etc. (WWF, 2019). This concept would likely be of interest to producers. It is important to stress that the implementation of such a system must be followed by a significant budget. The interest of the regional or national government appears to be essential.

During the study, the small difference between the selling price and the production price was highlighted. The promotion of labelling appears to be relevant for increasing the selling price of producers and promoting wastewater treatment. Awareness of the benefits of labelling could be a lever for promoting the project.

Second, the graph below shows the assessment of environmental quality. First, it is noted that only one farmer responded that the environment was good, 41.4% considered the environment as fair, while 48.3% assessed the environment as bad. These figures reveal that some farmers are aware of the environmental problem.

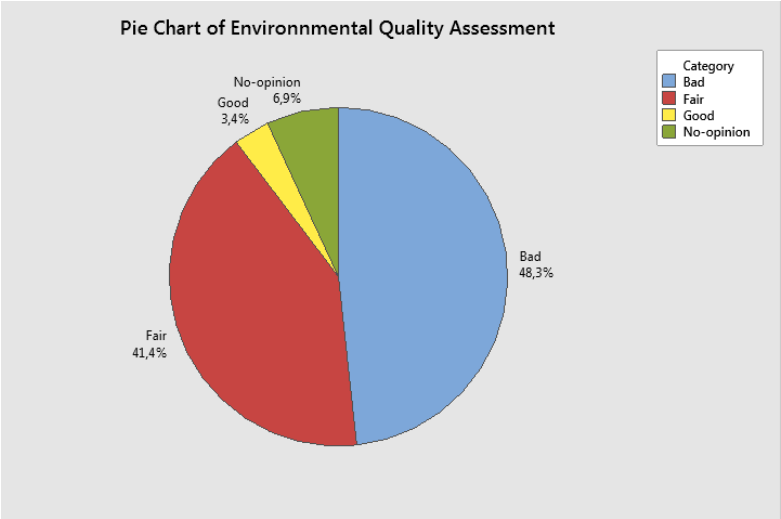


Figure 54: Pie chart of the environmental quality assessment of the farmers interviewed

But when farmers were asked for possible improvements, improving irrigation and water treatment before production were the main answers. These responses reveal that the problem for farmers is upstream of production and that they have little interest in water after production. Thus, awareness campaigns seem important to make farmers sensitive to the issue and make farmers aware of the benefits of water treatment after production. Indeed, water treatment after production will benefit shrimp production by reducing water pollution. Good quality water is one of the most effective prophylactic measures to control disease, which is the first source of economic losses for shrimp producers.

Third, the production of microalgae requires significant management. Microalgae production will likely take place outside. However, an infection of the pond can occur by zooplankton, for example. Eliminating an infection requires skills and knowledge of the biology of microalgae and their pests.

Thus, the implementation of water treatment by microalgae could be more collective than individual. The installation of a wastewater treatment plant for all the ponds in a production area seems more feasible, but this solution also has its limitations.

- To be able to treat the wastewater from all the ponds in an area, all the wastewater must be discharged into the same places. However, wastewater is discharged anarchically in the two municipalities studied. Investments in infrastructure would therefore be necessary to enable all wastewater to be collected at one point.
- As the cultivation of microalgae is long, the area required to treat wastewater would potentially be significant.

Profitability in both cases is essential for producer investment. According to an interview with the aquaculture department of Ninh Thuan, the plan of the province is to maintain the same production areas and stop cultivation outside the authorised areas. The stated objective is to develop an aquaculture area, particularly in An Haï, which is highly developed and with technologies that provide sustainability. The RENEWABLE project could contribute to this objective on condition that the necessary funds for this development are released.

To conclude, as the RENEWABLE project's technology is still at its experimental stage, it is difficult to assess the feasibility of the project. Nevertheless, it is important to take into account the difficulties the project will likely encounter to develop a technology adapted to these constraints.

12 REFERENCES

Alongi, D. M. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science*. https://doi.org/10.1016/j.ecss.2007.08.024

ASC. (2019). *New ASC-VietGAP Benchmark Provides Guidance for Vietnamese Farmers*. Retrieved from Aquaculture Stewardship Council: https://www.asc-aqua.org/news/latest-news/new-asc-vietgap-benchmark-provides-guidance-for-vietnamese-farmers/

Beresford, M. (2008). Doi Moi in review: The challenges of building market socialism in Vietnam. *Journal of Contemporary Asia*, Vol. 38, pp. 221–243. https://doi.org/10.1080/00472330701822314

Boi, N. V. Q. (2001). Aquaculture and environmental issues in the region of Nai Lagoon , Ninh Hai district , Ninh Thuan province , Viet Nam. *Methodology*.

Braun, G., Braun, M., Kruse, J., Amelung, W., Renaud, F. G., Khoi, C. M., … Sebesvari, Z. (2019). Pesticides and antibiotics in permanent rice, alternating rice-shrimp and permanent shrimp systems of the coastal Mekong Delta, Vietnam. *Environment International*, *127*(April), 442–451. https://doi.org/10.1016/j.envint.2019.03.038

Briggs, M., Funge-Smith, S., & P. Subasinghe, R. (2005). *Introductions and movement of two penaeid shrimp species in Asia and the Pacific.* Rome: Food and Agriculture Organization of the United Nations.

Chaudhry, P., & Ruysschaert, G. (2008). Human development Report 2007/2008 : Viet Nam case Study. *Natural Hazards*.

CIA. (2018). *The World Factbook.* Washington, DC.

Coface. (2019). *Economic studies : Vietnam*. Retrieved from Coface: https://www.coface.com/Economic-Studies-and-Country-Risks/Vietnam

Crab, R., Defoirdt, T., Bossier, P., & Verstraete, W. (2012). Biofloc technology in aquaculture: Beneficial effects and future challenges. *Aquaculture*, *356–357*(August), 351–356. https://doi.org/10.1016/j.aquaculture.2012.04.046

Dao, T. (2019, February 27). *Viet Uc to open new high-tech shrimp farm in April, preps to sell pangasius fingerlings*. Retrieved from Seafoodsource: https://www.seafoodsource.com/news/aquaculture/viet-uc-to-open-high-tech-shrimp-farm-in-april-preps-to-sell-pangasius-fingerlings

European Commission. (2019, june 30). *EU-Viet Nam free trade agreement - Joint press statement by Commissioner Malmström and Minister Tran Tuan Anh*. Retrieved from http://trade.ec.europa.eu: http://trade.ec.europa.eu/doclib/press/index.cfm?id=2041

FAO. (1995). Code of Conduct for Responsible Fisheries. *Food and Agriculture Organization of the United Nations*, 41. https://doi.org/ISBN 92-5-103834-5

FAO. (2003). Penaeus vannamei. *Fao*, 1–14. https://doi.org/10.1111/j.1365-2109.2009.02291.x

FAO. (2018). *State of Fisheries and Aquaculture in the world*. https://doi.org/issn 10

General Statistics Office of Vietnam. (2017). *Agriculture , Forestry and Fishing*. 437–548.

Hays, J. (2008). *DOI MOI (VIETNAM'S ECONOMIC REFORMS) AND VIETNAM'S ECONOMY DURING THE 1980s AND 1990s*. Retrieved from Fact and details: http://factsanddetails.com/southeast-asia/Vietnam/sub5_9g/entry-3470.html

Hishamunda, N., Bueno, P., Ridler, N., & Yap, W. G. (2011). Analyse du développement de l'aquaculture en Asie du Sud-Est - Une perspective de la politique. In *FAO Fisheries and Aquaculture*.

Hop, H. T. M. (2012). *Integration of farmers in the shrimp subsector in the Mekong River Delta, Vietnam*.

Hung, L. T., & Quy, O. M. (2013). On farm feeding and feed management in whiteleg shrimp (Litopenaeus vannamei) farming in Viet Nam. *On-Farm Feeding and Feed Management in Aquaculture*, *583*, 337–357. Retrieved from ftp://ftp.fao.org/fi/Cdrom/T583/root/12.pdf

Jim Chappelow. (2019, Juli 15). *Centrally planned economy*. Retrieved from Investopedia: https://www.investopedia.com/terms/c/centrally-planned-economy.asp

Martinez-Porchas, M., & Martinez-Cordova, L. R. (2012). World aquaculture: Environmental impacts and troubleshooting alternatives. *The Scientific World Journal*, *2012*(June 2014). https://doi.org/10.1100/2012/389623

Naylor, R. L., Mooney, H., Goldburg, R. J., Primavera, J. H., Kautsky, N., Folke, C., … Lubchenco, J. (2000). Effect of aquaculture on world fish supplies. *Nature*, *405*(6790), 1017–1024. https://doi.org/10.1038/35016500

Nguyễn Văn Long. (2009). Cá rạn san hô ở vùng biển ven bờ NAm Trung Bộ. *Tạp Chí Khoa Học và Công Nghệ Biển*, 38–66.

Nguyen, H., & Grote, U. (2018). Agricultural Policies in Vietnam: Producer Support Estimates, 1986-2002. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3249374

Nguyen, T. B. T. (2015). Good Aquaculture Practices (VietGAP) and Sustainable Aquaculture Development in Viet Nam. *International Workshop on Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia 2014*, 85–92. https://doi.org/10.1016/S0140-6736(09)62038-9

Shinn, A. P., Pratoomyot, J., Griffiths, D., Trong, T. Q., Vu, N. T., Jiravanichpaisal, P., & Briggs, M. (2018). Asian Shrimp Production and the Economic Costs of Disease. *Asian Fisheries Science*, *31*(December), 29–58.

Thang, B. T. (2000). After the war : 25 years of economic development in Vietnam. *NIRA Review Spring 2000 Vol. 7 No. 2*, 2–6.

Tien, V. D., & Griffiths, D. (2009). *Shrimp Aquaculture in Vietnam : Best Practice and Future Direction*. 1–21.

UNDP. (2019). *Country profiles : Vietnam*. Retrieved from United Nations Development Program : http://hdr.undp.org/en/countries/profiles/VNM

Unicef. (2019). *Vietnam statistics*. Retrieved from Unicef.org: https://www.unicef.org/french/infobycountry/vietnam_statistics.html

VASEP. (2019, Juli 12). *Sector profile : Shrimp*. Retrieved from Portal of Vietnam Association of Seafood Exporters and Producers: http://seafood.vasep.com.vn/669/onecontent/sector-profile.htm

Vinacert. (2019). *Vietgap Certification*. Retrieved from VinaCert Certification and Inspection Joint Stock Company: http://www.en.vinacert.vn/se/vietgap-certification

World Atlas. (2019). *Vietnam*. Retrieved from WorldAtlas.com: https://www.worldatlas.com/webimage/countrys/asia/vn.htm

World Bank. (2016). An Overview of Agricultural Pollution in Vietnam: The Aquaculture Sector 2017. *The World Bank*, 1–79. https://doi.org/doi:10.1596/29246

World Bank. (2019). *Viet Nam*. Retrieved from https://donnees.banquemondiale.org/pays/viet-nam

World Commission on Environment and Development. (1987). Our Common Future. *Our Common Future*, 300. https://doi.org/10.1080/07488008808408783

13 APPENDICES

13.1 QUESTIONNAIRE

Date of interview (Ngày):

Phone number:

1. General information (Thông tin chung)

    a. Full name of interviewee (Tên người được phỏng vấn):
    b. Hamlet (Địa chỉ):
    c. Age of householder (Tuổi của chủ hộ):

2. Information for agricultural production (Thông tin sản xuất)

    a. Area of homestead land 2019(ha) Diện tích đất nông trại hiện nay:
    Area of owner(ha):

    b. Area of agricultural land (ha): …..

Origin of land (nguồn gốc của đất): o inherit (thừa kế) o buying (mua) o other(PLs detail) Khác :

    c. Area of rented agricultural land (Diện tích đất nông nghiệp thuê) (ha):

Rental (VND Million/ha) (tiền thuê):

Renting time (year) (thời gian thuê):

    d. Area of land for rent since 2017(Diện tích đất thuê từ năm 2017):

Time for rent (Thời gian thuê): Year of rent (Số năm thuê):

Rental (VND mill/ha) (Tiền thuê):

    e. Income of crops in 2018 (Lợi tức từ trồng trọt năm 2018)

Crop (Vụ)	Area (diện tích)	VND mill/year (số tiền /năm)

    f. Income of livestock in 2018 (Lợi tức từ chăn nuôi) 2018

Animal (vật nuôi)	Number of animal (số lượng)	Selling price (giá bán)	Income(VND mill/year) (Lợi tức)

g. Income of other agricultural activities in 2018 (Một số hoạt động nông nghiệp khác)

Activity (hoạt động)	Income (VND mill/year) (Lợi nhuận)

h. Income of aqua-products, excludes shrimp (Thu nhập của các sản phẩm thủy sản, không bao gồm tôm)

Income 2018 (VND mill/year)	
Area of pond for fish (m^2)	
Area of …	
Area of …	
Area of …	
Area of …	
Area of …	

i. Credit

If family borrow money last 2 years? (Gia đình bạn có mượn tiền trong vòng 2 năm qua không?)
Yes o o No

if yes (nếu có):

	2018
Amount (Mill VND). Số tiền	

Reasons:

h. Non-farm activities (Hoạt động phi nông nghiệp)

Does any family member work in non-farm activity? (Có thành viên nào trong gia đình làm việc trong các hoạt động phi nông nghiệp không?)

Yes (Có) o No (Không) o
If yes (nếu có)

Activity (Hoạt động)	Number of people (số người)	Income (mill VND/person/month) (thu nhập)
Worker at a factory (công nhân viên chức)		
Trader (buôn bán)		

Handcraft worker (công nhân thủ công)		
Other (khác)		

3. INFORMATION OF SHRIMP PRODUCTION (Thông tin về sản xuất Tôm)

Year of starting cultivation (năm bắt đầu nuôi tôm):

Type of farm cultivation (loại hình nuôi):

Intensive (Mật độ cao) Semi-intensive : extensive (mật độ thấp):

Change of cultivation since starting (thay đổi việc nuôi trồng kể từ khi nào)? Có hay không?

o Yes o No

Which change (thay đổi nào):

If yes (nếu có), Consequences (kết quả): Improvement (sự cải thiện)?

a. Shrimp cultivation area 2017 (m²): Of which, area of water surface (Diện tích nuôi trồng năm 2017: trong đó diện tích mặt nước chiếm):

b. Shrimp cultivation area 2018 (m²): Of which, area of water surface (Diện tích nuôi trồng năm 2018: trong đó diện tích mặt nước chiếm):

c. Shrimp cultivation area 2019 (m²): of which, are of water surface (Diện tích nuôi trồng năm 2019: trong đó diện tích mặt nước chiếm):

d. Shrimp species (Giống tôm)

2010	2017	2018	2019

e. Number of crop/year (số lượng vụ mùa/năm):

f. Cultivation duration (Thời gian nuôi trồng)

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
2017												
2018												

2019												

Do the family change the cultivation type since starting? Gia đình có thay đổi nuôi trồng từ khi bắt đầu không?

Reason of change (lý do thay đổi):

g. Shrimp cultivation density (mật độ nuôi)

	2017			2018		
	Crop 1	Crop2	Crop3	Crop 1	Crop 2	Crop 3
Number of postlarvae/m² (số lượng tôm /m²)						

h. Place to buy post larvae: (nơi mua con tôm giống)

In the village (trong làng)	
In the other district in Ninh Thuan province (ở huyện khác trong tỉnh)	
Other village in the same district (ở làng khác trong tỉnh)	
In other province (ở tỉnh khác)	

I. Input cost (chi phí đầu vào)

Shrimp cultivation capital (Nguồn vốn nuôi tôm) ?

Source of capital (Nguồn vốn)	Amount 2017(Mill VND)	Amount 2018(Mill VND)

Fixed cost: infrastructure cost? (Chi phí cố định: cơ sở hạ tầng)

Investment	Cost (Mil VND)
Pond construction (xây dựng ao)	
Canal Construction (xây dựng kênh đào)	

Pond preparation (sửa chữa ao)	
Water treatment (xử lý nước)	
Water pump (bơm nước)	
Net system (hệ thống mạng lưới)	
Ventilation system (hệ thống quạt nước)	
Well construction	
Other	

Analysis of the last production

Cost of input supply for shrimp cultivation (chi phí đầu vào cho nuôi tôm)

Number of postlarvae per m^2:

Total ponds area:

Number of ponds:

1. Cost of post-larvae:

2. Feedstuff:

Name of the product	Quantity	Price

- How many types of food did you use for your shrimp throughout the growing season? The price of each type of food (per kg, per 50 kg, depends on farmers' memory)? How many days did you give the first / second / third type of shrimp food? How many times a day do you feed your shrimp? and the amount used for once?

3. Chemical

a. Shrimp treatment

Name of the product	quantity	Price

- How many types of products did you use to avoid shrimp disease? The price of each type of products (per kg, per 50 kg, depends on farmers' memory)?How many days did you give the first / second / third type of products ?How many times a day do you have your shrimp? and the amount used for once?

b. Water treatment

Name of the product	quantity	Price

-- How many types of products did you use to avoid shrimp disease? The price of each type of products (per kg, per 50 kg, depends on farmers' memory)? How many days did you give the first / second / third type of products? How many times a day (or week) do you apply treatment for your shrimp? and the amount used for once?

Output (đầu ra)

	Production (kg)	Price (1000VND/kg) 2018
Crop 1		
Crop 2		
Crop 3		

Labour cost: (Chi phí nhân công)

	2018
Number of family member participated in the cultivation (Số thành viên trong gia đình làm việc)	
Number of hired labour for cultivation (Số lao động được thuê)	

Price of hired labour (Thousand VND/month) Giá thuê vnd/ tháng	

a. Year with loss of production? (Có bị mất mùa không?

Yes o No o

b. Year without shrimp production? (Có năm nào không sản xuất tôm không)

Reasons (Lý do)

Viral disease (dịch bệnh)	
Temperature (nhiệt độ)	
Pollution (ô nhiễm)	
Other	

c. Did you observe a change in the shrimp production last years ? (Có thấy sự thay đổi trong sản xuất tôm giống trong năm vừa qua?)

Yes o No o

If yes, explain:

d. Assessing environmental quality (Đánh giá chất lượng môi trường)

o Good (Tốt) o Fair (khá tốt) o Bad (kém) o no opinion(Không ý kiến)

e. Reason of bad environment quality (Lý do chất lượng môi trường kém)

Freely discharging waste (Xả thải tùy ý)	
Lack of treatment systems (Thiếu hệ thống xử lý)	
Low awareness of culturists (Thiếu ý thức của chủ chăn nuôi)	

Other	

f. Way of improvement? (Cách cải thiện)

Seed testing before stocking (Kiểm tra giống trước khi thực hiện)	
Improving pond environment (Cải thiện môi trường ao)	
Enhancing community awareness (Nâng cao ý thức cộng đồng)	
Other?	

g. Did you observe positive change concerning the environment of work ? (Bạn có thấy sự thay đổi tích cực liên quan đến môi trường làm việc?

O Yes o No

Details:

13.2 DESCRIPTIVE STATISTICS

Statistic

Variable	Survey	N	N*	Mean	SE Mean	StDev	Minimum
Age of the householder	An Haï	15	0	43,53	2,10	8,13	28,00
	Phuong Haï	14	0	45,86	2,45	9,18	30,00
Area of agricultural land (Hectare)	An Haï	15	0	0,836	0,127	0,491	0,225
	Phuong Haï	14	0	1,033	0,153	0,572	0,230
Rental price VND	An Haï	11	4	133636364	42731141	141723162	40000000
	Phuong Haï	3	11	31333333	29356052	50846173	0
Year of starting cultivation	An Haï	15	0	2014,5	0,496	1,92	2009,0
	Phuong Haï	14	0	2005,2	2,35	8,80	1990,0
Cultivation area 2018 (Hectareà	An Haï	15	0	0,836	0,127	0,491	0,225
	Phuong Haï	14	0	0,834	0,154	0,578	0,160
Number of crop/year	An Haï	15	0	3,0000	0,0845	0,3273	2,0000
	Phuong Haï	14	0	1,750	0,172	0,643	1,000
Cultivation duration (Days)	An Haï	15	0	91,000	0,724	2,803	90,000
	Phuong Haï	14	0	88,93	3,64	13,61	70,00
Stocking density (Postlarvae/m^2)	An Haï	15	0	201,7	18,2	70,6	60,0
	Phuong Haï	14	0	88,21	7,43	27,82	42,00
Yield 2018 (Tons/Ha)	An Haï	15	0	14,77	1,14	4,43	6,67
	Phuong Haï	14	0	7,16	1,41	5,29	0,00
Shrimp selling price (VND)	An Haï	15	0	122363	2979	11539	110000
	Phuong Haï	14	0	77361	7487	28015	0
Number of production Pond	An Haï	15	0	4,533	0,786	3,044	1,000
	Phuong Haï	14	0	2,071	0,385	1,439	1,000

Number of sedimentation	An Haï	0	15	*	*	*	*
Pond	Phuong Haï	14	0	1,357	0,169	0,633	1,000
Average Area/pond	An Haï	15	0	0,2029	0,0249	0,0963	0,1000
(Hectare/pond)	Phuong Haï	14	0	0,2950	0,0392	0,1467	0,1400
Number of hired labour	An Haï	15	0	1,800	0,296	1,146	0,000
	Phuong Haï	12	2	0,833	0,271	0,937	0,000
Cost of postlarvae	An Haï	15	0	109,47	5,32	20,62	50,00
(VND/Ha)	Phuong Haï	14	0	68,07	9,08	33,98	12,00
Cost of chemical	An Haï	15	0	914272645	86973898	336848457	474236723
(VND/Ha)	Phuong Haï	14	0	53532146	17279370	64653482	15446429
Cost of Postlarvae	An Haï	15	0	672681667	72440733	280561754	150000000
(VND/Ha)	Phuong Haï	14	0	62339406	16380343	61289632	6857143
Cost of Feedstuff	An Haï	15	0	1983186725	163379651	632766667	915200000
(VND/Ha)	Phuong Haï	14	0	206410340	31338222	117256889	34821429
Cost of electricity	An Haï	15	0	254885621	33441605	129518781	75000000
(VND/Ha)	Phuong Haï	14	0	31179242	2742054	10259826	16666667
Variable costs	An Haï	15	0	3825026657	276672655	1071548583	1875374964
(VND/Ha)	Phuong Haï	14	0	353461134	58726610	219734853	76544643
Depreciation Costs	An Haï	15	0	171393174	19027696	73693951	72000000
(VND/Ha)	Phuong Haï	14	0	27297839	6508078	24350997	0
Cost of pond preparation	An Haï	15	0	380143791	61736343	239103830	150000000
(VND/Ha)	Phuong Haï	14	0	38582262	15739901	58893317	3636364
Fixed costs	An Haï	15	0	551536964	74606492	288949701	240740741
(VND/Ha)	Phuong Haï	14	0	65880101	18258637	68317562	3636364
Gross added value	An Haï	15	0	1441335180	176940907	685289188	179660625
(VND/Ha)	Phuong Haï	14	0	191906218	94724736	354427508	-169594286
Net added value	An Haï	15	0	1269942006	168556703	652817304	29660625
(VND/Ha)	Phuong Haï	14	0	164608380	90983141	340427742	-183308571
Labour costs	An Haï	15	0	146429194	22805938	88327017	0
(VND/Ha)	Phuong Haï	14	0	19199456	7508690	28094945	0
Rental price	An Haï	15	0	142755991	48905858	189411575	0
(VND/Ha)	Phuong Haï	14	0	4162801	3648982	13653242	0
Return to family labor	An Haï	15	0	980756821	146233182	566358679	-295672708
(VND/Ha)	Phuong Haï	14	0	141246122	89346575	334304272	-183308571
Production cost	An Haï	15	0	114030	5456	21129	91579
(VND/kg)	Phuong Haï	13	1	91727	11019	39729	52232

Variable	**Survey**	**Q1**	**Median**	**Q3**	**Maximum**
Age of the householder	An Haï	37,00	43,00	51,00	57,00
	Phuong Haï	38,25	46,00	52,25	65,00
Area of agricultural land	An Haï	0,400	0,600	1,200	1,700
(Hectare)	Phuong Haï	0,558	0,900	1,550	1,900
Rental price	An Haï	50000000	80000000	120000000	500000000
VND	Phuong Haï	0	4000000	90000000	90000000
Year of starting	An Haï	2014,0	2015,0	2015,0	2017,0
Cultivation	Phuong Haï	1998,8	2001,0	2014,0	2018,0
Cultivation area 2018	An Haï	0,400	0,600	1,200	1,700
(Hectareà	Phuong Haï	0,268	0,715	1,350	2,000
Number of crop/year	An Haï	3,0000	3,0000	3,0000	3,5000
	Phuong Haï	1,000	2,000	2,000	3,000

Cultivation duration	An Haï	90,000	90,000	90,000	100,000
(Days)	Phuong Haï	75,00	90,00	100,00	115,00
Stocking density	An Haï	160,0	200,0	275,0	300,0
(Postlarvae/m^2)	Phuong Haï	68,75	95,00	105,00	133,00
Yield 2018	An Haï	13,33	15,50	18,52	20,00
(Tons/Ha)	Phuong Haï	3,54	6,83	9,62	20,00
Shrimp selling price	An Haï	110000	120000	130000	150000
(VND)	Phuong Haï	71857	86158	95750	107000
Number of production	An Haï	3,000	4,000	4,000	12,000
Pond	Phuong Haï	1,000	2,000	2,250	6,000
Number of sedimentation	An Haï	*	*	*	*
Pond	Phuong Haï	1,000	1,000	2,000	3,000
Average Area/pond	An Haï	0,1113	0,2000	0,2500	0,4000
(Hectare/pond)	Phuong Haï	0,1900	0,2500	0,4200	0,6000
Number of hired labour	An Haï	1,000	2,000	2,000	5,000
	Phuong Haï	0,000	0,500	2,000	2,000
Cost of postlarvae	An Haï	95,00	113,00	130,00	130,00
(VND/Ha)	Phuong Haï	38,75	65,00	102,50	110,00
Cost of chemical	An Haï	571377346	881471232	1289182399	1434166732
(VND/Ha)	Phuong Haï	23654406	32800125	53252562	267729643
Cost of Postlarvae	An Haï	513000000	678000000	877500000	1106875000
(VND/Ha)	Phuong Haï	32532468	42978733	66818182	232941176
Cost of Feedstuff	An Haï	1345882353	2127840000	2542222222	2745600000
(VND/Ha)	Phuong Haï	135264536	190794000	291209091	467300000
Cost of electricity	An Haï	175000000	233333333	300000000	533333333
(VND/Ha)	Phuong Haï	23409091	29824561	40648977	46428571
Variable costs	An Haï	2826377346	3942571232	4685221732	5357266732
(VND/Ha)	Phuong Haï	237146329	302358187	395799191	1004735525
Depreciation Costs	An Haï	96000000	180000000	226666667	300000000
(VND/Ha)	Phuong Haï	9271978	14357143	50703349	76490441
Cost of pond preparation	An Haï	258823529	300000000	450000000	1125000000
(VND/Ha)	Phuong Haï	8125000	16941176	30357143	200000000
Fixed costs	An Haï	380000000	520000000	630000000	1425000000
(VND/Ha)	Phuong Haï	27101648	43642857	90422744	258181818
Gross added value	An Haï	997152066	1394935744	1954778268	3042733268
(VND/Ha)	Phuong Haï	-47587195	65277914	341933626	1135264475
Net added value	An Haï	738328537	1181602411	1714778268	2742733268
(VND/Ha)	Phuong Haï	-54190157	41124264	320012197	1058774034
Labour costs	An Haï	80000000	120000000	222222222	300000000
(VND/Ha)	Phuong Haï	0	0	34833333	81818182
Rental price	An Haï	0	100000000	177777778	750000000
(VND/Ha)	Phuong Haï	0	0	0	51136364
Return to family labor	An Haï	585563277	1087696477	1606778268	1722733268
(VND/Ha)	Phuong Haï	-61868405	20781334	296012197	988185798
Production cost	An Haï	100986	102504	132213	161728
(VND/kg)	Phuong Haï	58700	86760	105184	192093