Working Group for Sustainable Use of Natural Resources
School of Business and Economics
Philipps- University of Marburg

# Dissertation

Nguyen Tan Dat

# Sustainable livelihood strategy for shrimp farmers in Mekong Delta under the climate change context. A case study in Tra Vinh province, Vietnam

First supervisor: Prof. Dr. **Björn Vollan**
Second supervisor: Prof. Dr. **Michael Kirk**
Date of submission: 15 September 2020
Place: Marburg

# Declaration

Full name: Nguyen Tan Dat

Birthday: 15.07.1982

Place birth: Tra Vinh, Vietnam

I declare that this thesis is my own account of my research and contains as its main content work that has not previously been submitted for any tertiary education institution.

Marburg, 15.09.2020

# Acknowledgements

First and foremost, I would like to express my great gratitude and appreciation to Professor Dr. Björn Vollan who accepted me after one hopeless year in finding supervisor, he gave me a big opportunity to pursue my dream. In deep my heart to thank and respect him, a principal supervisor, for his excellent supervision and encouragement during this doctoral research. Likewise, I am deeply indebted to Professor Dr. Michael Kirk, my second supervisor, for his guidance. I am grateful to, my colleagues, Matthias Mayer, Ivo Steimanis, Lukas Kampenhuber, Macro Nilgen and Maximilian Burger, for their willingness to share their experience, as well as their valuable comments and suggestions on the papers. Especially, I am grateful to Matthias for his translation the summary into German with all kindness. I am also very grateful to my friend, Chung N.V for his invaluable advices when I was in stressful status during this doctoral research.

My sincere thanks to the Marburg International Doctorate (MID) program for giving me the financial support to my fieldwork in Vietnam for three months. Acknowledgement is also given to the main financial support provided by the International Cooperation Department, Ministry of Education and Training of Vietnam (VIED) for during my study in Germany.

My great appreciation is given to the school of Economics and Law, Tra Vinh University for their valuable support and encouragement during my doctoral study. My sincere thanks are extended to local authorities in Tra Vinh province, especially those in Duyen Hai and Cau Ngang districts for their valuable comments, support and nice cooperation during my survey. I would like to thank assistants and all interviewees who used their time for my questionnaire with the honest answers in the ten villages of both Duyen Hai and Cau Ngang districts.

I would like to express all of my heart-feeling gratefulness to my parents and my parents-in-law who always encouraged me with such love and support my wife taking care two daughters.

Finally, from the depth of my heart, I would like to give a very special thank you to my wife Duong Hien Ngoc Lan, my two daughters Nguyen Duong Ngoc Han and Nguyen Duong Phuc An. They always supported me and encouraged me with their best wishes. My wife was always there cheering me up and stood by me through the good and bad time during my research journey.

Thank you.

# Zusammenfassung der Dissertation

Innerhalb der letzten Jahre hat die Brackwassergarnelen-Zuchtindustrie große Gewinne erwirtschaftet. Tatsächlich entwickelt sich die Industrie seit 1980 stetig weiter (EASRD, 2006; MARD, 2015). Sie wurde vom Norden bis zum Süden Vietnams kultiviert, insbesondere im Mekong-Delta, wo sie im Jahr 2014 91% (699,725 Hektar) der Garnelenzuchtfläche ausmachte, mit einer durchschnittlichen Wachstumsrate von 3.12% pro Jahr von 2010 bis 2014 (MARD, 2015). Im Jahr 2018 machte die Garnelenproduktion im Mekong-Delta etwa 83% der gesamten nationalen Garnelenproduktion aus und besaß eine durchschnittlichen Wachstumsrate von 8.85% pro Jahr von 2010 bis 2018 (GSO, 2020). Die Provinz Tra Vinh ist eine von zwölf Provinzen im Mekong-Delta. Mit einer 65 km langen Küstenlinie und einem dichten System von Flüssen und Kanälen, eignet sie sich besonders gut für die Zucht von Brackwassergarnelen. Nach Angaben des Ministeriums für natürliche Ressourcen und Umwelt der Provinz Tra Vinh existieren 110 Kanäle der Stufe 1 mit einer Gesamtlänge von 467 km; 690 Kanäle der Stufe 2 mit einer Gesamtlänge von 2.110 km und 8,800 Kanäle der Stufe 3 mit einer Länge von 6,620 km. Die Behörden aus Tra Vinh bezeichnen die Garnelenzuchtindustrie als eine bedeutende Wirtschaftstrategie für die Region. Bis 2019 dehnte sich die Garnelenzucht in der Provinz Tra Vinh auf 33,378 Hektar aus und erreichte 67,768 Tonnen Garnelenproduktion mit einer durchschnittlichen Wachstumsrate von 21.5% pro Jahr von 2010 bis 2019 (Aquaculture Department of Tra Vinh). Darüber hinaus hat die Provinz Tra Vinh, durch den Beschluss 784/QD-UBND "Entwicklung der Garnelenzuchtindustrie bis 2025" vom 27. April 2018, verfügt die Garnelenproduktion auf Grundlage der jeweiligen natürlichen Gegebenheiten zu Entwickeln. Währenddessen solle die Entwicklung und Anwendung von intensiven und halbintensiven Produktionsmethoden und Technologien in der Landwirtschaft vorangetrieben werden. Die Anwendung dieser Methoden soll dazu dienen die Nutzung von Chemikalien und Antibiotika in der Landwirtschaft zu unterbinden und ein Öko-Umweltzertifikat zu erhalten, welches den Anforderungen der Exportmärkte entspricht.

Die Garnellenindustrie sieht sich jedoch ernsthaft mit Umweltproblemen konfrontiert. Laut MARD (2015) lag der Verschmutzungsgrad der Flüsse über dem 2.5- bis 3-fachen des zulässigen Standards. Das kurzfristige Gewinnstreben der Bauern in der Garnelenzucht, geht auf Kosten der Umwelt. Sie beachten nicht die Folgen des Missbrauches von nicht überwachten oder verbotenen Chemikalien und Medikamenten in der Garnelenzucht. Dies geschieht trotz vorhandener Umweltschutzgesetze. In Tra Vinh gibt es besonders viele kleine Farmen, die häufig ihr komplettes Land für Garnelenteiche verwenden, ohne jedoch Schmutzwasserbecken anzulegen, die die Chemikalien und Abfälle abfangen könnten. Abwässer werden daher häufig direkt in die Flüsse und Kanäle geleitet, was die Wasserverschmutzung zusätzlich erhöht. Wird das verschmutzte Wasser für neue Kulturen verwendet, ohne dieses davor zu reingingen, besteht ein hohes Risiko für den Ausbruch von Krankheiten in den Garnellenkulturen.

Laut Angaben der Abteilung Aquakultur der Provinz Tra Vinh, hat die Garnelenzuchtindustrie durch den Klimawandel innerhalb der letzten Jahre erhebliche Schäden und Verluste erlitten. Im Jahr 2019 meldeten über 6,200 Garnellenzüchter Schäden durch Trockenheit, Temperaturschwankungen, und den Ausbruch von Krankheiten erlitten zu haben. Insgesamt waren 2,121 Hektar, 19% der gesamten von Kleinbetrieben bewirtschafteten Fläche, betroffen (Abteilung Aquakultur der Provinz Tra Vinh). Von 1970 bis 2007 stieg die Durchschnittstemperatur um 0.6° Celsius, und die durchschnittlichen Niederschläge nahmen um 94 mm pro Jahr zu (MARD, 2015). Bis 2100 werden unter dem A2-Szenario eines Anstiegs des Meeresspiegels um 1 Meter (SLR) 85% des Gebietes des Mekong-Deltas (12,376 $km^2$) versinken. Insbesondere in der Provinz Tra Vinh werden bis zu 45.7% der Fläche an Naturland verloren gehen, und das Küstenland für die Aquakulturzucht wird vollständig verschwinden (Carew-Reid, Jeremy, 2007). Gleichzeitig wird mit dem Meeresspiegelanstieg auch die Durchschnittstemperatur auf schätzungsweise 30°C ansteigen, was bis 2100 fast alle Wirtschaftsbereiche, insbesondere aber die Garnelenzucht, betreffen wird (MORE, 2008). Nach dem Szenario A2 des IPCC werden die Niederschläge in diesem Gebiet bis 2050 und bis 2100 um etwa 3% bzw. 7% zunehmen, so dass die Provinz Tra Vinh in Zukunft voraussichtlich mehr Niederschläge erleiden wird. Die gilt insbesondere für die Küstengebieten, die am besten für die Garnelenzucht geeignet ist (JICA, 2013).

Um trotz dieser schlechten Aussichten, den bereits existierenden Klima Unsicherheiten, sowie den vorhanden Wasserverschmutzungsproblemen einen Gewinn erzielen zu können, werden immer mehr Chemikalien und Medikamente in der Garnelenzucht eingesetzt. Diese zunehmende Verwendung von Medikamenten und Chemikalien ist nicht nur für die Umwelt und das natürliche Ökosystem schädlich, sondern kann auch aufgrund der in den Garnelen vorhanden Rückständen der Produktion die Gesundheit der Konsumenten beeinträchtigen. Aufgrund dieser Probleme haben einige internationale Abnehmer das Vertrauen in die vietnamesische Aquakultur verloren. Laut MARD wurden in den letzten Jahren einige Garnelen Exportprodukte aufgrund von Antibiotikarückständen und Bedenken der Ernährungssicherheit von internationalen Abnehmern abgelehnt. Daher fällt es den vietnamesischen Garnelen schwer, auf neue ausländische Märkte vorzudringen, und sie werden von den traditionellen Märkten streng beobachtet. Zum Beispiel müssen derzeit 100% der Garnelensendungen aus Vietnam vom japanischen Zoll kontrolliert werden, anstatt der bisher üblichen 30%; auch Korea warnte davor, Nitofuran Rückstände in Garnelenprodukten aus Vietnam gefunden zu haben (VASEP, 2020). Das Ministerium für Landwirtschaft und ländliche Entwicklung (MARD) führte daher 2011 den Vietnam Good Aquaculture Practice (VietGAP)-Standard ein, um nachhaltige Produktionsmethoden der Aquakulturindustrie zu fördern. Die VietGAP ist der Leitfaden für die Aquakulturpraxis und umfasst fünf grundlegende Kriterien: sichere Lebensmittel, sichere Gesundheit der Garnelen, eine sichere Umwelt, soziale Verantwortung und Informationen zur Rückverfolgung. Kernstück der VietGAP ist der Kriterienkatalog für ökologische und umweltbezogene Anforderungen an den Prozess der Garnelenzucht. Dieser verfolgt das Ziel, die regulierenden Funktionen der Natur zu maximieren, indem Umweltbedingungen geschaffen werden, die die nachhaltige Entwicklung der Garnelenzucht begünstigen, wobei die natürlichen Ressourcen so weit wie möglich geschont werden sollen. Gegenwärtig ist die Regierung zutiefst beunruhigt und ermutigt die Bauern, den VietGAP-Standard in der Garnelenzucht anzuwenden. Das MARD ging davon aus, dass VietGAP bis 2020 von 80 Prozent der Garnelenzüchter angewendet werden würde. Die derzeitige Zahl der zertifizierten Betriebe ist jedoch mit insgesamt nur 128 Garnelenfarmen unbedeutend (vietgap.tongcucthuysan.gov.vn). In der Provinz Tra Vinh gibt es nur einen Garnelenzüchter, der ein VietGAP-Zertifikat erhält.

Die Garnelenzucht ist die wichtigste Lebensgrundlage für mehr als 44,000 Haushalte in der Provinz Tra Vinh (Aquakulturabteilung von Tra Vinh), deren Existenz durch den Klimawandel und der von der Garnelenzucht verursachte Verschmutzung der Wasserressourcen bedroht ist. Ziel der Dissertation ist es, den aktuellen Stand der Lebensgrundlagen der Garnelenzüchter zu bewerten, die die ökologische Nachhaltigkeit in der Garnelenzucht beeinflussen, und den Livelihood Vulnerability Index (LVI) gegenüber dem Klimawandel zu analysieren. Ein weiteres Ziel der Dissertation ist es herauszufinden, unter welchen Umständen Garnelenzüchter die Voraussetzungen des VietGap Zertifikates in ihrem Betrieb umsetzen würden. Die Dissertation besteht aus drei Studien, deren Beitrag zum aktuellen Stand der Wissenschaft werden im Folgenden kurz zusammengefasst.

In Kapitel 2 werden die Daten aus der Provinz Tra Vinh von 300 Haushalten, die in der Garnelenzucht tätig sind, durch Fragebogeninterviews und Transect Walks gesammelt. Die Studie basiert auf dem Sustainable Livelihood Framework des DFID, welcher 5 Typen umfasst: Humankapital; Naturkapital; physisches Kapital; Sozialkapital und Finanzkapital, um den aktuellen Stand der Lebensgrundlagen der Garnelenzüchter zu analysieren. Die Studie zeigt auf, dass die derzeitige Existenzgrundlage und das Niveau der ökologischen Nachhaltigkeit von extensiven, intensiven und halbintensiven Landwirtschaftssystemen in der Rangfolge aufsteigend bewertet wurden. Drei Lebensgrundlagen, das menschliche, das natürliche und das finanzielle Kapital stehen in einer positiven Beziehung zur ökologischen Nachhaltigkeit in der Garnelenzucht. Insbesondere die intensive Grundwassernutzung und die oftmals nicht vorhandene Abwasserreinigung in der Garnelenzucht war für die Garnelenzucht im Hinblick auf die Umweltverträglichkeit nicht nachhaltig.

In Kapitel 3 misst die Studie den Livelihood Vulnerability Index (LVI) der Garnelenzüchter gegenüber dem Klimawandel, indem sie drei Garnelenzuchtsysteme in der Provinz Tra Vinh, Vietnam, miteinander vergleicht. Die Analyse basiert auf dem Rahmenwerk des IPCC zur Bewertung der Anfälligkeit der drei Dimensionen Ausbeutung, Empfindlichkeit und Anpassungsfähigkeit. Im Rahmen des Sustainable Livelihood Framework (SLF) von Chambers and Conway (1992) wurden insgesamt 42 Indikatoren für die Dimensionen vorgeschlagen, die den Kapitalien des Lebensunterhalts entsprechen (menschliches, physisches, natürliches, soziales und finanzielles Kapital). Insgesamt wurden 300 Haushalte befragt. Davon betrieben 195 intensive, 62 halbintensive und 43 extensive Produktion. Im Allgemeinen deuten die Ergebnisse darauf hin, dass die Garnelenzüchter auf einer mittleren Ebene anfällig waren. Die Extensiv Haltung war unter den drei Methoden der Garnelenzucht, die am stärksten durch den Klimawandel gefährdete. Insbesondere die intensive Landwirtschaft war in Bezug auf Naturkapital, Sozialkapital und Finanzkapital sehr anfällig für den Klimawandel, während die umfangreiche Landwirtschaft am anfälligsten für Sach- und Humankapital war. Obwohl die intensive Garnelenzucht in der Regel angemessener in Anlagen und Ausrüstung investiert wird, war sie aufgrund der hohen Besatzdichte anfälliger für den Klimawandel als die semi-intensive.

Kapitel 4 verwendet die Methode der kontingenten Bewertung, um herauszufinden, welche Faktoren die Entscheidung der Landwirte beeinflussen, der VietGAP-Zertifizierung zu folgen ($WTA_{Decision}$) und wie viel Subventionswert sie bereit sind zu akzeptieren ($WTA_{Subsidy}$), um den VietGAP-Standard zu verfolgen. Die Ergebnisse zeigten, dass $WTA_{Decision}$ positiv mit Bildungsniveau der Landwirte, der Wahrnehmung der Umwelt und der Einstellung gegenüber dem VietGAP-Zertifikat korrelieren, während dieselben Faktoren negative mit der von den Farmern erwartete Auswirkung einer $WTA_{Subsidy}$ korreliert sind. Das Jahreseinkommen hatte auch einen leichten Einfluss auf die Bereitschaft der Landwirte, einen Subventionswert zu akzeptieren. Die Ergebnisse der Studie legen nahe, dass die Behörde die Subvention in der ersten Phase des Programms erhöhen sollten, um die Landwirte zur Teilnahme zu bewegen. In der der Folge sollte dann gezielt das Umweltbewusstsein der Garnelenzüchter gestärkt werden, um die langfristigen Vorteile des VietGAP-Zertifikats hervorzuheben, um noch mehr Garnelenzüchter zur Teilnahme zu bewegen.

Diese Forschung leistet Beiträge zur nachhaltigen Existenzstrategie von Garnelenzüchtern im Kontext des Klimawandels.

- Aufstellung der Kriterien für die ökologische Nachhaltigkeit der Garnelenzucht
- Herausfinden der Beziehung zwischen den Vermögenswerten zum Lebensunterhalt und der ökologischen Nachhaltigkeit der Garnelenzucht.
- Zusammenstellung der Indikatoren für drei Dimensionen der Bewertung der Verwundbarkeit gegenüber dem Klimawandel auf der Grundlage der fünf Lebensgrundlagen.

- Herausfinden des Unterschieds zwischen den drei Garnelenzuchtsystemen in Bezug auf die Verwundbarkeit des Lebensunterhalts gegenüber dem Klimawandel.

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## Abbreviation

| | |
|---|---|
| ASC | Aquaculture Stewardship Council |
| BOD | Biochemical Oxygen Demand |
| DFID | Department for International Development |
| DO | Dissolved Oxygen |
| FAO | Food and Agriculture Organization |
| GAA | Global Aquaculture Alliance |
| GlobalGAP | Global Good Aquaculture Practice |
| GSO | General Statistic Organization |
| IFAD | International Fund for Agricultural Development |
| IPCC | Intergovernmental Panel on Climate Change |
| JICA | Japan International Cooperation Agency |
| LVI | Livelihood Vulnerability Index |
| MARD | Minister of Agriculture and Rural Development |
| MONRE | Minister of Natural Resource and Environment |
| MOFI | Minister of Fishery |
| SLR | Sea level rise |
| VASEP | Vietnam Association of Seafood Exporters and Producers |
| VietGAP | Vietnam Good Aquaculture Practice |
| WB | World Bank |
| WTA | Willingness to accept |

# Chapter 1: Introduction

## 1.1 The Mekong river system

The system originated in China and flows through five countries: Myanmar, Laos, Thailand, Cambodia and Vietnam. It is ranked eighth in the world in terms of discharge at about 15,000$m^3$/s, twelfth in terms of longest rivers in the world (4,500 km) and twenty-first in terms of largest areas in the world (795,000 $km^2$) (MRC-Mekong River Commission). When the Mekong River reaches Vietnam, it divides into two branches, one called Song Tien (Tien River) and the other Song Hau (Bassac River). And then each of these divides again into six rivers and three rivers, respectively. This is why it is called Song Cuu Long (meaning "nine rivers" or "nine dragons") by the Vietnamese. In Vietnam, the Mekong Delta is not only named after a bowl of rice but is also the biggest area for aquaculture cultivation with the most aquatic productivity, especially when it comes to shrimp farming.

## 1.2 The Mekong Delta

The Mekong Delta is located in south Vietnam between $8^0$30'N-$10^0$40'N latitude to $104^0$26'E-$106^0$40'E longitude. It includes eight coastal provinces: Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau, Kien Giang, Long An, and the inland provinces of Hau Giang, Vinh Long, An Giang and Dong Thap. There is also the province-level municipality of Can Tho. The total natural area is 4,046,400 ha, with 80.3% of its area used for agriculture and aquaculture. The brackish shrimp industry is developing especially rapidly in the eight coastal provinces with 780 km of coastline and 22 main estuaries covering 600 to 800 ha of tiding areas (GSO, 2019). In 2014, total shrimp farms took up 699,725 ha and accounted for 91% of national shrimp-farming land. The industry produced 661,074 tons of shrimp (2014), which is equivalent to 80.61% of the total national production, which is 1.5 times higher compared to 2010 (MARD, 2015).

## 1.3 Tra Vinh province

Tra Vinh province is located in the northwest Mekong Delta, Vietnam. It lies between $9^0$31'46" N-$10^0$4'5" N latitude and $105^0$57'16" E -$106^0$36'04" E longitude, belonging to the 12 provinces of the Mekong Delta. It has quite plain topography and an elevation above sea level of approximately one meter. It also has a 65km coastline. The annual average temperature ranges from $26^0$C to $27.6^0$C. The annual average of precipitation is about 1,520 mm, the humidity 84%, and annual total hours of sunshine reaches 2,556 hours. Tra Vinh lies between two main river branches, the Co Chien River and Hau River, both of which originate from the Mekong River. Inland, it has a dense network of rivers and canals cover the province. Along with nine natural rivers and 12 tributaries, there are many artificial canals serving agriculture and aquaculture activities. There is a total area of 2,341 $km^2$, a population of 1,009,168 (as of 2019) and a density of 443 people per $km^2$ (GSO, 2019).

The advantage of a dense network of rivers and canals is that it is favourable to the shrimp-farming industry developing throughout the province. There are four shrimp-farming districts, and Duyen Hai and Cau Ngang are the two most prominent of the four shrimp-farming regions in Tra Vinh province (Hiep et al., 2016). In 2018, both districts accounted for 93.32% of the shrimp-farming area and 89% of productivity in the province (Aquaculture Department of Tra Vinh province). They are coastal districts suitable for brackish shrimp farming, but they are also susceptible to sea-level rise, storms and drought (791/QD-UBND, dated 7 April 2016).

### 1.4 Climate change context

Climate change is manifested mostly through phenomena such as increasing temperature and sea-level rise, which is considered a huge challenge for the human race worldwide. It has explicit and implicit impacts on a wide range of areas in our life: economics, environment, society and health. No country is beyond the impact of climate change, and no country can fight it alone. Climate change demands that all countries around the globe come together to alleviate the negative impacts of climate change. According to Maplecroft (2010) and IFAD (2011), Vietnam was ranked 13th in the world in terms of vulnerability to climate change. Importantly, Vietnam is considered one of five Asian countries in danger of being seriously affected by sea-level rise (SLR) and rising temperatures. In the last five decades, Vietnam's annual average temperature increased by 0.7°C, and the sea level rose 20 cm. The 'El Nino' and 'La Nina' phenomena affected Vietnam more seriously than ever (MONRE, 2008), and average precipitation rose more 94 mm per year (MARD, 2015).

By 2100, under the A2 scenario of one-meter sea-level rise (SLR), approximately 10% of the population will be affected directly with a loss of 10% of GDP (WB, 2007). It will lead to be inundated 85% of the Mekong Delta area (12,376 sq. km). Tra Vinh province in particular will lose up to 45.7% of its natural land area and coastline for aquaculture farming (Carew-Reid & Jeremy, 2007). Accompanying SLR, the average temperature was estimated to increase by $3^{\circ}C$, which will affect almost all economic sectors in general and shrimp farming in particular by the year 2100 (MONRE, 2008). According to scenario A2 of IPCC, the rainfall in this area will increase by about 3% and 7% by 2050 and 2100, respectively. Thus, it is predicted that Tra Vinh province will be hit with more excessive rainfall in the future, especially in coastal areas that are considered most suitable for shrimp farming (JICA, 2013).

Considering the unpredictability and severity of climate change, aquaculture production was experiencing substantial difficulties caused by rising temperatures, sea-level rise, freshwater surface scarcity, contaminated water resources and disease outbreaks. In terms of climate patterns, the trend of long droughts in the dry season and heavy precipitation in the rainy season will be increasingly apparent in the future (IPCC, 2007; MARD, 2015).

**1.5 Aquaculture overview**

Coastal areas serve as home to more than 2.4 billion people and 40% of the world population (Ocean Conference, United Nations, New York, 5-9 June 2017). In Vietnam 51.7% of the population, equivalent to 40 million or more people, were living on natural resources along 2,600 km coastlines from north to south (EASRD, 2006; IFAD, 2011). Aquaculture cultivation plays an important role in improving the livelihoods of millions of farmers along coastlines in Southeast Asia (IPCC, 2001). The shrimp industry in Vietnam started in the 1980s when it was an undeveloped and low-tech industry that depended on wild shrimp seed for stocking and made occasional use of homemade feed. Shrimp farming traditionally used primitive extensive systems with low yield. But by the 1990s, with more investment in technologies like aeration systems, formulated foods, advanced aquatic chemicals and development of artificial hatcheries, the semi-intensive and intensive farming systems began to expand quickly.

From 1990, aquaculture cultivation became an important livelihood for farmers and was an accurate measure for economic prosperity in general. In the last five years, shrimp production accounted for an average of 43.9% of total national aquaculture production and earned 3.376 billion USD annually from exports (Table 4.1). The shrimp industry in particular has become a principal sector that contributes to economic development in the Mekong Delta (Ha et al., 2013; Anh et al., 2010). The Vietnamese government has paid special attention to aquaculture activities, shrimp farming in particular, which accounted for 79.54% of total aquaculture production from 2010 to 2018 (GSO, 2019).

Tra Vinh province is one of eight provinces with a shrimp industry in the Mekong Delta. The province has an average production growth rate of 24% per year, and annual shrimp production accounts for approximately 41,000 tons or 7.35% of total shrimp production in the Mekong Delta over five years (GSO, 2019). Therefore, the shrimp industry is considered instrumental in the reduction of poverty and creation of employment opportunities (Ha et al., 2013). According to MARD (2015), an average of 2-3 labours per ha are dependent on the intensity of shrimp farming. By 2020, Vietnam had 1.2 million labours participating in this sector, and that number is predicted to reach 1.3 million labours in 2030.

Although aquaculture production has been successful in recent years in the Mekong Delta, this mode of production faces several risks and challenges, especially from diseases, environmental pollution, rejected export shipments and climate change factors. In fact, almost all the rivers and canals around shrimp-farming areas are polluted; they were reported that the pollution was two to three times over the permitted level (MARD, 2015). There are many causes of this pollution, but aquaculture is known to be the most prominent. Because of high profits coming from the shrimp industry, the farmers are shortsighted in their environmental responsibilities. To solve the problem of water resource pollution in farming, farmers usually choose such short-term measures as using more chemicals and drugs in shrimp farming (Kim et al., 2020). Moreover, small-scale farms are popular in Tra Vinh province, and they utilise almost all their land for shrimp ponds but do not have reservation ponds. Hence, discharged wastewater directly emptied into rivers or canals is a major cause of polluted water resources. And a vicious cycle becomes evident when farmers use that water for new crops: this is a big risk for disease outbreaks. According to the Aquaculture Department of Tra Vinh province, the shrimp-farming industry has suffered significant damage and losses in recent years. In 2019, there were 6,238 intensive and semi-intensive shrimp farming households damaged, with 2,121ha damaged due to drought, fluctuation of temperature and epidemic disease. This accounted for 19% of the total shrimp-farming area.

In recent years, extreme weather patterns in temperature and precipitation have occurred in the Mekong Delta. For instance, the rise in temperature has both advantages and disadvantages. The shrimp's metabolism increases when the water temperature rises, which could promote the shrimp's digestion and enhance the shrimp growth rate. On the other hand, a process of organic decomposition also increases along with high water temperature, leading to low dissolved oxygen (DO) which is one of the main causes of shrimp dying off en masse (Kam et al., 2012). Regarding salinity intrusion, Nguyen et al. (2020) concluded that Tra Vinh is the most vulnerable place among all the provinces in the Mekong Delta. Both temperature rise and seawater intrusion stimulate groundwater for compensating for evaporation and balancing the degree of salinity in ponds. While rainfall reduces the degree of salinity in ponds, causing stress to shrimp.

Furthermore, to struggle against the negative effects of climate change leads to use of more chemicals or antibiotics to treat diseases, and the consequence of abusing those substances is an increase in rejected shipments in exporting activity which accounted for 80% of shrimp production in Vietnam (MARD, 2015). While there are more opportunities to serve major export markets like the EU, America and Japan, these markets require high-quality shrimp products. Hence, in 2011 the Ministry of Agricultural and Rural Development (MARD) promulgated the Vietnam Good Aquaculture Practice (VietGAP) standard to address how the aquatic industry could develop sustainably. The VietGAP is the guide for aquaculture practice in Vietnam, comprising five fundamental criteria: safe food, safe shrimp, safe environment, social responsibility and traceability. However, the current number of certified farms is insignificant, with only 128 shrimp farms in total (vietgap.tongcucthuysan.gov.vn). In particular, there is only one shrimp farmer getting a VietGAP certificate in Tra Vinh province.

Therefore, to develop the shrimp industry in Tra Vinh province, this study approaches the sustainable livelihood strategy for shrimp farmers adapting to climate change. First, based on the Sustainable Livelihood Framework (DFID, 1999) suitable indicators must be chosen for livelihood capitals to calculate the value of shrimp farmers' livelihood assets. And composed the criteria to measure the environmental sustainability of shrimp farming (*env_sus*). Afterwards, there should be analysis of how the livelihood capitals affect the *env_sus*. Second, the vulnerability assessment method was applied to analyse the Livelihood Vulnerable Index of three shrimp farming systems to find solutions for alleviating the vulnerability of shrimp farming. Third, the willingness to accept a subsidy for getting a VietGAP certificate in shrimp farming is considered. That assesses the extent of shrimp farmers' contributions to a sustainable environment.

## 1.6 Research questions

Considering the climate change context and shrimp-farming problems mentioned above, this study will attempt to answer the following questions:

What are the shrimp farmers' livelihood assets? How do the livelihood assets affect the environmental sustainability of shrimp farming?

How are shrimp farmers' livelihoods vulnerable to climate change?

Are shrimp farmers willing to change over from traditional shrimp farming to eco-environmental practices (VietGAP standard)? And how much a minimum subsidy would they be willing to accept to get a VietGAP certificate?

## 1.7 The findings of this thesis

Based on the research questions above, the research has found the following. First, the study showed that shrimp farmers in Tra Vinh province had moderate livelihood asset values. Issues of financial capital were a big problem for shrimp-farming households. A majority of farmers found it difficult to access financial credit to invest in farming due to their small-scale operation and the low value of pledged land. In terms of natural capital, some risks were exposed. Prevailing use of groundwater in shrimp farming with no reservation pond could not meet the conditions of sustainable shrimp farming. The 19 criteria chosen to measure the environmental sustainability of shrimp farming, and in general all farming systems achieved an over mean level of environmental sustainability. This study found that human, natural and financial capitals have a positive effect on the environmental sustainability. In specifically, environmental sustainability had a positive relationship with shrimp farmers who had more experience in shrimp farming and who have reservation ponds, access to financial credit, or a high annual income. While farm size had a negative effect on the environmental sustainability.

Secondly, the study assessed the Livelihood Vulnerability Index under the Intergovernmental Panel on Climate Change (LVI-IPCC) of shrimp-farming households through several indicators based on five livelihood assets in the context of climate change. The study results reported that extensive shrimp-farming households' livelihoods were the most vulnerable to climate change. This is because extensive shrimp farmers had high sensitivity but low adaptive capacity to climate change in almost livelihood capitals, especially with human and physical capitals. In addition, these families are located in the coastal areas with ponds damaged due to sea-level rise and tidal waves. While intensive shrimp farmers were the second vulnerable to climate change. However, in terms of natural, financial, and social capitals, this farming system was the highest vulnerability (Fig.3.10). Especially, it was highly sensitive to polluted water resources, and exposed problems such as disease outbreaks, using groundwater in farming due to irregular climate patterns such as drought, fluctuated temperature between night and day. Furthermore, intensive shrimp farmers found it difficult to access credits from banks and relatives due to the frequency of lost crops. Be similar to the intensive farming system in terms of technology production, but with lower density stock, the semi-intensive shrimp farming was the least vulnerable to climate change.

Thirdly, the VietGAP certificate is valuable not only for its positive economic aspects but also is an indication that farmers are taking responsibility for long-term environmental preservation. And this certificate is also required for the sustainability of shrimp farming. The farmers would contribute to creating a positive image of Vietnam's shrimp products under the VietGAP standard. When their shrimp products are accepted into the wider world, this helps the Vietnamese economy become integrated with other international economies. One could conclude that the VietGAP standard is not beneficial to shrimp farmers in the short term in the sense that it will not increase productivity, their bottom-line profits, or make their shrimp disease free. In the long term, however, their commitment to sustainable development in terms of environmental preservation will create a good image and reputation, and the VietGAP certification has a good international reputation but with a lower certification cost compared to other international certifications (ASC, GlobalGAP, etc.). Application of VietGAP standard would help reduce the risk of rejected shrimp shipments and could help gain access to potential import markets. The study used the contingent valuation method (CVM) to analyse the factors affecting shrimp farmers' decisions ($WTA_{Decision}$) whether to accept a subsidy for the VietGAP certificate, and a minimum subsidy value that farmers are willing to accept ($WTA_{Subsidy}$) or a subsidy for pursuing VietGAP certificate. It found that $WTA_{Decision}$ considered farmers' education levels, environmental perceptions and attitudes toward the VietGAP certificate. These factors had negative effects on $WTA_{Subsidy}$. Also, the farmers' annual income also slightly influenced farmers' willingness to accept a subsidy value. The findings of the paper are not only relevant to Tra Vinh province but also to all provinces engaged in shrimp farming or aquaculture in general.

### 1.8 Conclusion of thesis

This thesis brought a perspective of the shrimp industry in the Mekong Delta in general and in Tra Vinh province in particular under a climate change context. The study employed the sustainable livelihood framework to analyse the current status of shrimp farmers' livelihood assets as well as evaluating the effects of those on the environmental sustainability of shrimp farming.

Several studies in the literature have been published concerning the vulnerability assessment in aquaculture sectors. However, no study has used the quantitative method to measure the degree of vulnerability to climate change. This study makes an important contribution to quantifying the livelihood vulnerability of shrimp farmers to climate change by composing a list of appropriate indicators based on three dimensions (exposure, sensitivity and adaptive capacity).

Shrimp farming in Tra Vinh is divided into three systems: extensive, semi-intensive and intensive. The main differences of those systems are the intensity of stock and integrated technologies. This study found that the semi-intensive farmer had the highest-valued livelihood assets and was the least vulnerable to climate change. The extensive shrimp farming system was the polar opposite of the semi-intensive system. Likewise, the degree of environmental sustainability of each farming system was ranked in order from the highest to the lowest for semi-intensive, intensive and extensive systems, respectively. The results imply that in a climate change context, shrimp farming needs to invest more in facilities and equipment to adapt to changes in climate patterns. The semi-intensive and intensive farming systems are more suitable for adaptation to climate change than the extensive system. Therefore, extensive farming should gradually revert to semi-intensive or intensive methods to reduce vulnerability to climate change. However, the higher-intensity farming would be more at risk of adverse environmental effects if there is a low environmental perception. Encouraging shrimp farmers to obtain eco-environment certificates like VietGAP is the best option for sustainable shrimp farming in the future.

Based on the results of the thesis, I can judge this study's limitations and give some recommendations for future studies. First, the study has just referred to the environmental sustainability of shrimp farming, but the sustainable development of an agricultural entity should include economic, social and environmental aspects (Valenti et al., 2011; Chowdhury et al., 2015), thereby future studies could elaborate on these overlooked dimensions.

Secondly, regarding the livelihood vulnerability assessment, this study found it difficult to approach the secondary data of Tra Vinh's climate change patterns, so the study could not analyse the direct relationship between climatic factors (temperature, precipitation, sea-level rise) and shrimp farmers' livelihood. It would be better if future research could collect those data to get the whole picture of the climate change vulnerability assessment.

Thirdly, the study was limited to factors affecting the willingness to accept a subsidy for getting a VietGAP certificate. Due to the shortage of farmers who experienced the VietGAP standard of farming in the research sites, the study could not collect data related to the efficiency of this model to compare it with non-VietGAP farming. Thus, it may be difficult for respondents to decide on adoption of the incentive program. In the future, studies should compare productivity of VietGAP and non-VietGAP farming systems to emphasise the important role of sustainability in shrimp farming.

In conclusion, through analysis of livelihood assets of shrimp farmers, this thesis evaluated the current status of livelihood assets, the vulnerability of this livelihood and the factors affecting the willingness to accept a subsidy to pursue a VietGAP certificate which plays an important role in achieving the sustainable livelihood strategy for shrimp farming.

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# Chapter 2: Analyse how livelihood assets affect the environmental sustainability of shrimp farming: A case study in Tra Vinh province, Vietnam.

**Abstract**

This study is based on the DFID's Sustainable Livelihood Framework, which lists five types of capital to analyze the current status of shrimp farmers' livelihood assets: human capital, natural capital, physical capital, social capital, and financial capital. The data was collected from 300 shrimp-farmer households in 2019 in Tra Vinh province through questionnaire interviews and transect walks. The purpose of the study is to estimate the effects of five forms of livelihood capital and 17 indicators on the environmental sustainability of shrimp farming which is measured by 19 criteria. The study revealed that three forms of livelihood capital and five indicators have statistical significance affecting the environmental sustainability of shrimp farming in Tra Vinh. It was found that using groundwater in shrimp farming was not environmentally sustainable. Conversely, having reservation ponds had a positive impact on environmental sustainability.

## 2.1 Introduction

The shrimp industry is facing with a serious environmental problem. According to MARD (2015), the degree of pollution in rivers was 2.5 to 3 times the permitted standard (Table 2.1). And 80% of surveyed shrimp farmers recognised the problem. Because of the high profits in the shrimp industry, shrimp farmers can be short sighted when it comes to environmental responsibility. They were ignoring the effects of certain prohibited chemicals sometimes used in shrimp farming, in spite of well-known regulations and environmental protection laws. Moreover, small-scale farms are popular in Tra Vinh province, as they utilise land for shrimp ponds, but they do not have reservation ponds. Hence, wastewater gets directed to rivers or canals, which leads to polluted water resources. And a vicious cycle occurs when farmers use that polluted water for new crops: it is a big risk for disease outbreaks. According to the Aquaculture Department of Tra Vinh province, the shrimp farming industry has suffered significant damage and loss in recent years. In 2019, there were

6,238 shrimp farming households damaged with 2,121ha of shrimp farming losses due to drought, fluctuation of temperature, and epidemic disease. These losses accounted for 19% of total shrimp farming area excluding extensive production.

**Table 2.1. Standard environment required for shrimp cultivation**

| Parameter | Unit | Optimal range | |
|---|---|---|---|
| | | Black tiger shrimp | White leg shrimp |
| pH degree of water | ------- | 7.5-8.5 | 7-9 |
| Temperature | Celsius | 28-33 | 18-33 |
| Salinity | ‰ | 15-25 | 5-35 |
| Transparency | m | 0.4-0.5 | 0.2-0.5 |
| $H_2S$ | mg/l | <0.02 | <0.05 |
| $NH_3$ | mg/l | <0.1 | <0.3 |
| DO (dissolved oxygen) | mg/l | >=3.5 | >=4.0 |

Source: MOFI, 2006; Anh et al., 2010; Tra Vinh Department of Science and Technology.

Obviously, environment plays a crucial role in aquaculture in general, and it seriously affects the shrimp industry. Shrimp are highly sensitive to adverse environmental changes such as quality of water, degree of salinity, the temperature of water, and pH degree (Kongkeo & Phillips, 2001). In shrimp farming, water resources are considered a “common pool,” which is used free of charge. Hence, the quality of the water resource is dependent on the farmer’s behavior or environmental perception when it comes to resource management. In fact, aquaculture cultivation was faced with increasingly severe instances of polluted surface water due to directly discharge without proper treatment. However, in order to continue their work, the majority of farmers used groundwater to supplement shrimp ponds during the crop. In other words, the farmers transfer the common resource to private resource. Overexploitation of groundwater sooner or later leads to subsidence issues, which exacerbate flooding and seawater intrusion inevitably. There were approximately two million wells extracting 2.8 million $m^3$/day of groundwater in Mekong Delta, in which Tra Vinh accounted for 88,833 wells and exploited 224,773 $m^3$/day (Bui et al., 2017). Groundwater exploitation is the main cause of subsidence in the Mekong Delta, Vietnam. Its average rate of subsidence was about 1.1 cm annually over the past 25 years, and this trend is likely to increase in the near future (Minderhoud et al., 2017).

In Vietnam, the brackish shrimp farming industry has brought large profits for farmers in recent years. In fact, this industry has been developing since 1980 (EASRD, 2006; MARD, 2015). It was cultivated across the north and south of Vietnam, especially in the Mekong Delta, where it accounted for 91% (699,725 hectares) of national shrimp farming land in 2014, with an average growth rate of 3.12% per year from 2010 to 2014 (MARD, 2015). In 2018 shrimp productivity in the Mekong Delta accounted for nearly 83% of the total national shrimp production, with an average growth rate of 8.85% per year from 2010 to 2018 (GSO, 2020). In particularly, Tra Vinh province is one of 12 provinces in Mekong Delta suitable for brackish shrimp cultivating with a 65km coastal line and a dense system of rivers and canals. According to Department of Natural Resources and Environment of Tra Vinh province, there are 110 canals at level 1 with a total length of 467 km; 690 canals at level 2 with a total length of 2,110 km; 8,800 canals at level 3 with a length of 6,620 km. Tra Vinh authority considers the shrimp industry to be a vital economic asset. By 2019 Tra Vinh province's shrimp farming land expanded to 33,378 hectares and achieved 67,768 tons of shrimp production with an average growth rate of 21.5% per year from 2010 to 2019 (Aquaculture Department of Tra Vinh; Table 2.2). However, in 2016 the total area of shrimp farming decreased dramatically compared with the previous year due to the El Niño weather systems that prevailed from 2015 to 2016. In addition, Decision 784/QD-UBND of Tra Vinh province dated 27 April 2018 'Developing shrimp farming industry to 2025', has planned to develop shrimp production based on each natural condition area. Whereas the intensive and semi-intensive methods should continually develop and apply new technology in farming without abusing chemicals and antibiotics, going forward it will be mandatory to acquire a certificate showing that farmers are meeting the exporting market requirements. And the extensive shrimp farming industry should combine its resources to preserve the existing mangrove forests and to help balance the ecosystem.

**Table 2.2. Area and productivity of shrimp industry in Tra Vinh province**

| Year | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| **Area** | 24,832 | 27,801 | 23,692 | 30,707 | 32,600 | 33,378 |
| **Output** | 37,033 | 34,926 | 37,862 | 43,043 | 52,823 | 67,768 |

*Source:* Department of Aquaculture of Tra Vinh province.

All the above problems mentioned pose challenges to sustainable shrimp farming in terms of environment. Therefore, this study would like to compare the current status of livelihood assets of three shrimp farming systems and find out how livelihood assets affect the environmental sustainability of shrimp farming in Tra Vinh province.

## 2.2 Methodology

### 2.2.1 Literature reviews

There are several definitions of sustainability that depend on the perspective of each author or institution. But there is some general agreement on particular points. In general, sustainability concerns three important pillars: economic, environmental, and social development (Valenti et al., 2011; Chowdhury et al., 2015). And to achieve sustainability, first the human race must alleviate poverty and ensure food security without exhausting our natural resources (DFID's Sustainable Livelihoods Approach and its Framework). For example, sustainable development utilizes all present resources without compromising future generations' livelihoods (Barbier, 2016). Therefore, in this study, the environmental sustainability of shrimp farming implies that the shrimp industry has to strike a balance between extracting natural resources and preserving them for their posterity. However, to measure sustainability, both qualitative and quantitative methods were employed by some authors when it came to finding suitable indicators. Chowdhury et al. (2015) looked at water quality, soil quality, and biodiversity loss to measure sustainability by the quantitative method. And sustainability combines with other economic and social institutional dimensions to gauge what constitutes sustainable shrimp farming. While Valenti et al. (2011) suggested a quantitative method to measure environmental sustainability in aquaculture with three indicators—natural resources, efficiency of natural resource use, and generated waste. The qualitative method is based on the list of improved environmental criteria for sustainable shrimp aquaculture to assess the impacts of shrimp farming on the environment (Noennback, 2002). Both methods worked perfectly for their respective purposes. However, they still did not present the final value of the environmental sustainability of aquaculture cultivation. This study is also based on the environmental sustainability criteria of those authors and experts' opinions to establish the list of criteria for the environmental sustainability of shrimp farming (Table 2.8). And the final value of environmental sustainability was normalised on an individual basis.

**2.2.2 Study area**

Tra Vinh province is located in the northwest Mekong Delta, Vietnam, between $9^0$31'46''N-$10^0$4'5''N latitude and $105^0$57'16''E -$106^0$36'04" E longitude, belonging to 12 provinces of the Mekong Delta. It has quite plain geographical features and an elevation above sea level of approximately 1 meter. It also has a 65km coastline. The annual average temperature is from $26^0$C to $27.6^0$C, and the annual average precipitation is about 1,520 mm. The average humidity annually is 84%, and annual total hours of sunshine reaches 2,556 hours. Tra Vinh lies between the Co Chien and Hau rivers, which flow from the Mekong River. Inland, there is a dense network of rivers and canals across the province, comprising nine natural rivers and 12 related tributaries, as well as an immense number of artificial canals serving agriculture and aquaculture. It has a total area of 2,341 $km^2$, a population of about 1,009,168 in 2019, and a density of 443 people per $km^2$ (GSO, 2019).

**2.2.3 Household survey**

The survey conducted interviewed 300 households in total. The household was selected randomly by each member of the team who was assigned to concentrate on a certain number of households for each village. This survey was repeated for each village until the process was complete. Our interviewing team had two members, and each member had to complete four surveys per day. The study started at the beginning of December 2018 and finished at the end of January 2019. There were 320 samples in total, after omitting uncompleted samples or illogically answered samples, there were 300 total samples for this study.

**2.2.4 Analyzing current status of livelihood assets of shrimp farmers**

The study analyses the current status of livelihood assets affecting strategies of sustainable shrimp farming. The livelihood assets based on the DFID's Sustainable Livelihood Approach and its framework which has five types: human capital; natural capital; physical capital; social capital and financial capital. Based on the conception of livelihood assets, the experts' discussion, characteristics of local shrimp farming, and actual fieldwork, 17 indicators were found for five livelihood assets to measure the value of each type of livelihood capital (Appendix 2.A).

Because each of the original value of indicators was calculated in different units or scales, they first would be normalized on the rating scale from 0 to 1 as the equation (1) if an indicator has a positive relationship with its type of livelihood capital (Hahn et al., 2009; Vincent, 2004; Antwi-Agyei et al., 2012; Urothody et al., 2010), otherwise using equation (2) for a negative relationship with its type of capital (Rajiv Pandey et al., 2017).

$I_{ij} = (X_{ij} - \mathbf{min}\ X_{ij}) / (\max X_{ij} - \min X_{ij})$ (1)

$I_{ij} = (\mathbf{Max}\ X_{ij} - X_{ij}) / (\max X_{ij} - \min X_{ij})$ (2)

Where $X_{ij}$ is original value of indicator $j^{th}$ of the livelihood capital $i^{th}$. The $i^{th}$ is human capital, natural capital, physical capital, social capital and financial capital.

$I_{ij}$ is the normalised average value of indicator $j^{th}$ and the livelihood capital $i^{th}$.

min $X_{ij}$ is the minimum value of indicator $j^{th}$ and the livelihood capital $i^{th}$.

max $X_{ij}$ is the maximum value of indicator $j^{th}$ and the livelihood capital $i^{th}$.

Then, value of each livelihood capital ($C_i$) is the average of all indicators of types of capital.

$$C_i = \sum_{j=1}^{n} \left( \frac{I_{ji}}{n} \right) \quad (3)$$

Value of $C_i$ from 0 to 1.

Equation (3) showed that the weight of each indicator is equal, which means every indicator in each capital has an equal degree of importance and influence. This approach has been employed in studies such as Eakin et al. (2008), Sulliva et al. (2002).

### 2.2.5 Analysing the effect of livelihood assets on the environmental sustainability of shrimp farming

The study estimates the impact of livelihood assets and the indicators on the environmental sustainability of shrimp farming. This study uses linear regression for analysis as follows:

$$\mathbf{Y_i = \alpha + \beta_k X_{ki} + \mu_i}$$

$\mathbf{Y_i}$ is the environmental sustainability of shrimp farming that is measured by the list of criteria (Table 2.8). $\mathbf{Y_i}$ is calculated by the number of "yes" answers dividing the total number of criteria, so its value is from 0 to 1. According to Roennback (2002), defining the regional and global criteria for environmental sustainability in shrimp aquaculture, and expert opinions, 19 criteria related to environmental sustainability of shrimp farming were selected as the following Table 2.8 shows.

$\mathbf{X_{ki}}$ represents explanatory variables: they are the five types of capital (human capital, natural capital, physical capital, social capital, and financial capital) for the first regression and second regression with 17 indicators. They are calculated in the above equations and mentioned in Appendix 2.A.

## 2.3 Results and discussion

### 2.3.1 Current status of livelihood assets of shrimp farmers

The survey conducted interviewing 300 households in total and divided into three sample groups: intensive (195 samples), semi-intensive (62 samples) and extensive production (43 samples).

**Human capital**

The age range of the shrimp farmer households surveyed in this study ranged from 24 to 66 years, whereas 56.67% were over 46 years old and 43.33% were under 45 years old. Therefore, average years of experience (H3) in shrimp farming was seven years, and only 10% of shrimp farmers had more than 10 years' experience. Looking at the 30-year history of the Vietnamese shrimp industry, the average years of experience of Tra Vinh shrimp farmers are quite modest. However, it is assumed that seven years is enough time to learn how important the role of the environment in shrimp farming is. In terms of shrimp-farming experience, the extensive-producing farmers were ranked the highest among the three methods of practice (Table 2.3). Extensive shrimp farming is the primary method of shrimp practice in this industry, which was inaugurated in 1980, while the other methods developed later (EARSD, 2006).

According to survey data, households were literate, with 23.33% having high school degrees, 43.33% secondary school degrees, and 33.33% with primary school degree. And the average family education level (H2) is nine years of schooling. Here, the intensive households were the most prominent because most were younger and wealthier, and their children had more educational opportunities. The extensive households had the lowest family education levels because their low incomes do not allow for many adequate educational opportunities.

The average household size was approximately four people, but 96% of families have non-labours with an average of two people per household being children or/and elderly; and 48.3% of families have semi-labour. Almost all members of shrimp-farmer families are involved in farming activities, but they do not take account of wages due to the prevailing social norms in Tra Vinh. As a result, average household labour capacity (H1) was quite low at around two members per household who could work. It means that most households were burdened with one out of two dependent members. There was no significant difference among the three methods of shrimp production.

Overall, the three indicators made human capital value lower than the medium value for all kinds of shrimp farming (Fig. 2.1). The intensive shrimp farmers' human capital in Tra Vinh was slightly higher than the others; this could be considered an advantage, as they are able to understand concepts of environmental responsibility. Semi-intensive and extensive were the opposite. Therefore, the higher-valued human assets would contribute to more environmental sustainability in shrimp farming.

**Table 2.3. Statistic values of indicators of human capital**

| **Indicator** | **scale** | **Unit** | **Intensive** | **Semi-intensive** | **Extensive** |
|---|---|---|---|---|---|
| Household labour capacity (H1) | Min<br>Max<br>Average | 1 labour<br>5 labours<br>2 labours | 0.301 | 0.352 | 0.384 |
| Household education level (H2) | Min<br>Max<br>Average | 5 years<br>13 years<br>9 years | 0.418 | 0.298 | 0.288 |
| Household experience in shrimp farming (H3) | Min<br>Max<br>Average<br>No | 0 year<br>20 years<br>7 years<br>40% | 0.359 | 0.348 | 0.373 |
| **Normalised value of human capital** | | | **0.359** | **0.332** | **0.348** |

**Natural capital**

The natural capital of shrimp farmers comprises four indicators: quality of water resource (N1), distance to water resource (N2), reservation pond (N3), and farm size per capita (N4). The study recorded 19% of shrimp farmers reporting that the water is slightly polluted, but highly polluted water was reported by 37.3% of farmers (Table 2.4). Water pollution has several causes, and this study reveals that aquaculture activity was cited by 63% of shrimp farmers as the main cause of water pollution. In recent years, scientists and authorities have been concerned about this issue because polluted water is one of the main causes of disease in shrimp. Effluents from shrimp ponds contain suspended soils, nutrients, residual chemicals, and pathogenic microorganisms. This problem is more severe in intensive rather than extensive shrimp farming. According to Anh et al. (2010), fertilizer and food waste discharged into surrounding surface water may reach 1 to 1.5 tons per ha in each crop for intensive shrimp farming. And due to the high cost for treating outlet water after harvesting or disposing of diseased shrimp ponds, there were some farmers discharging the polluted water directly into rivers or canals, which leads to diseases spreading to adjacent areas. The treatment cost of discharge water is between 4 to 5 million VND for 5,000m$^2$ pond size (Anh et al., 2010). In turn, the farmers pay high costs for treating water in ponds or treating disease in shrimp at an average of 14% to 15% of total production costs in intensive and semi-intensive farming (Sinh, 2005), or they may even experience crop losses and fall into debt. Because water pollution which carries a variety of pathogens or diseases resulting from polluted water discharged from shrimp ponds. It is presumed that all shrimp farmers should obey the rule of having their water treated before discharging it, avoiding the vicious cycle of disease spreading, pollution and sustaining the shrimp farming. The survey revealed that the semi-intensive shrimp farmers believed the quality of river water to be at the highest value (0.694), while the intensive farmers recorded the lowest values for quality of river water. The extensive farmers were as optimistic about their water quality as the semi-intensive farmers.

**Table 2.4. Statistic values of indicators of natural capital**

| Indicator | Scale | Percent | Intensive | Semi-intensive | Extensive |
|---|---|---|---|---|---|
| Quality of river water resource (N1) | Definitely unpolluted | 0% | 0.537 | 0.694 | 0.636 |
| | Low pollution | 19% | | | |
| | Generally polluted | 40.33% | | | |
| | Very polluted | 37.33% | | | |
| | Very highly polluted | 3.33% | | | |
| Distance to water resource (N2) | Under 30m | 78% | 0.867 | 0.910 | 0.912 |
| | From 30m to 50m | 19% | | | |
| | Over 50m | 3% | | | |
| Reservation pond (N3) | Yes | 60% | 0.651 | 0.823 | 0.000 |
| | No | 40% | | | |
| Farm size (N4) | <= 0.5 ha | 59% | 0.015 | 0.149 | 0.315 |
| | from 0.51ha to 2.0ha | 13% | | | |
| | > 2.0 ha | 28% | | | |
| **Normalised value of natural capital** | | | **0.518** | **0.644** | **0.466** |

Several drivers led to environmental pollution. Shrimp production is the main cause of polluted water and is itself a vicious cycle. The shrimp industry has rapidly expanded in recent years in both productivity and area covered (Table 2.2). Moreover, the majority of shrimp farmers work at a small-scale volume-wise: the survey data recorded that 59% of shrimp-farmer households own a farm (N4) less than 0.5ha in size, while households owning from 0.5 to 2ha of farmland accounted for 13%. This circumstance makes it difficult to control solid waste and wastewater in shrimp farming. It is beyond the local authority's ability to control all contravention in the term environment. Although there were several laws related to environmental protection promulgated in order to develop the shrimp industry into an environmentally sustainable business, the implication of the laws is weak. Under the Decision 784/QD-UBND of Tra Vinh province dated 27 April 2018, 'Developing shrimp farming industry to 2025' refers to improving environmental management systems with intensive and super-intensive shrimp production. The law mandates that a household owning a farm from 0.5 to 10ha in size has to sign an environmental declaration, and households with over 10 ha of farm size must report environmental effects periodically. In addition, the Circular No. 27/2015/TT-BTNMT dated 29 May 2015 requires all shrimp farmers to properly treat outlet water, and sediment and sludge must have reservation ponds equivalent to 10% to 15% of the pond size. Those legal actions were put forth in the hope that they would be steps forward in contributing to sustainable shrimp farming. However, there is a significant drawback in treating waste from shrimp production. In terms of technology, there are some feasible measures to eliminate effluents in ponds; that is, circulation water farming using beneficial algae and probiotics to deal with organic waste. But the cost burden for those measures becomes a significant obstacle for small-scale farmers, even if they act sustainably with respect to the environment and ecology. Another problem is that shrimp farmers are often not properly educated about the disseminated diseases and environmental risks. They are mainly concerned about their shrimp ponds and do not pay adequate attention to the water resources in rivers or canals that are more and more susceptible to untreated discharge water. In fact, when their neighbors were discharging polluted water into rivers or canals, these farmers were inclined to do the same. It seems that there is no benefit conflict in using the common pool.

As mentioned previously, shrimp farming is quite environmentally sensitive, especially in terms of water resources. Those farmers who do not reserve quality water for water exchange during the shrimp crops would be at risk of contracting disease from a common pool. Hence, the reservation pond (N3) plays a vital role in shrimp farming. Besides its function of storing water, it is also used to treat discharge water from shrimp ponds after harvesting crops. The data shows that 60% of shrimp farmers had reservation ponds; those without reservation ponds accounted for 40% of the total (Table 2.4). Specifically, those are numbers for intensive shrimp farming with 65% and semi-intensive shrimp farming with 82.3% have reservation ponds. Extensive shrimp farming does not need reservation ponds due to its particular characteristic. A majority of intensive and semi-intensive farmers who have no reservation pond would either accept the risk of polluted water when water is exchanged during crop or they might decide to use groundwater. And they have no options for treating discharge water, which is recognised as the main driver of polluted water in rivers and canals around shrimp farming areas. Although extensive shrimp farmers use less food and fewer chemicals compared to the other categories, extensive farming is still more or less harmful to the environment because of the dramatic loss of mangrove forest area in recent years. The extensive shrimp farming is located mainly in the Duyen Hai district where the mangrove forest area has declined from 12,797ha in 2001 (Thu et al., 2007) to 4,083ha in 2010, with the annual rate of reduction of mangrove forest being 6.8% (Hiep et al., 2016). Moreover, the adverse effects from the climate change context caused a shortage of brackish water in the dry season and higher salinity in water in the shrimp-farming areas. Hence, the reservation pond is required for all methods of practice.

Almost all shrimp farmers' ponds were relatively close to a water resource (N2) with 78% of them within 30 meters of a water resource, the average distance being about 28 meters (Table 2.4). Because shrimp farms are developing along rivers or canals, they are conveniently located near inlet and outlet water. According to the Department of Natural Resources and Environment of Tra Vinh province, there are 110 canals at level 1 with a total length of 467 km; 690 canals at level 2 with a total length of 2,110 km; 8,800 canals at level 3 with the length of 6,620 km. In general, shrimp farmers in Tra Vinh province have good access to water resources owing to the dense networks of rivers and canals. This indicator was favourable to all shrimp farming methods which are shown in Table 2.4 with relatively high values.

Overall, the current status of the natural capital of shrimp farmers in Tra Vinh was just at a medium level due to the four indicators mentioned above (Fig.2.1), in which the lowest value goes to extensive farming and the highest value to semi-intensive farming (Table 2.4).

**Physical capital**

In this study, I chose two indicators: the quality of the house (P1) and the household assets (P2) as physical capital. Referring to the quality of the house, 80% to 90% of all shrimp farmers were living in cement-and-brick houses. General data recorded 89% of shrimp-farming families living in level 4 houses made from cement and brick with corrugated iron roofs (Table 2.5) in general. This kind of house can last up to 30 years (Joint circular No. 07- LB/TT dated 30 September 1991). Just 11% of these families lived in a cottage-style house made from bamboo or mangrove wood with nipa palm leaf. Under caution from the Vietnam Disaster Management Authority, the level 4 houses could withstand winds up to grade 7 (on the Beaufort scale) in case of tropical low pressure and could be damaged in a typhoon. Because the Mekong Delta is located in the lower frequency typhoon area in general, and Tra Vinh province was affected only slightly by two typhoons (Category No.5- Linda storm in 1997 and Durian in 2006). However, shrimp-farming families could be at risk in extreme weather contexts.

One hundred percent of shrimp-farming households have three essential assets: televisions, cellphones, and motorbikes. Most of them also have a refrigerator for storing fresh foods (Table 2.5). But no one has a boat because almost all the families have access to roads, which is a more convenient and quicker way to travel than using small boats. The list of household furniture was chosen based on the living conditions of the farmers. Those items were essential assets that would help them lead more comfortable lives. As a result of the survey, 32.7% of families had five out of ten assets on the list. Three percent of families had a maximum of eight assets and 11% of families had a minimum of three assets. Overall, the value of this indicator (P2) was lower than the medium level, from 0.365 to 0.439 for semi-intensive, extensive, and intensive respectively.

Overall, two indicators mentioned previously contributed to the normalised value of physical capital higher than the average level, ranked in order by semi-intensive, extensive, and intensive households (Fig. 2.1).

**Table 2.5. Statistic values of indicators of physical capital**

| Indicator | Scale | Percent | Intensive | Semi-intensive | Extensive |
|---|---|---|---|---|---|
| Quality of house (P1) | cottage | 11% | 0.903 | 0.839 | 0.884 |
| | cement and brick (level 4) | 89% | | | |
| Household assets (P2) | television | 100% | 0.439 | 0.365 | 0.409 |
| | entertainment media | 42.33% | | | |
| | cell phone | 100% | | | |
| | motorbike | 100% | | | |
| | small boat | 0% | | | |
| | car | 0.33% | | | |
| | air conditioner | 15.67% | | | |
| | washing machine | 49% | | | |
| | refrigerator | 95.67% | | | |
| | internet access | 6.67% | | | |
| **Normalised value of physical capital** | | | **0.671** | **0.602** | **0.647** |

**Social capital**

Social capital refers to all benefits from relationships, community networks, and access to necessary information for livelihood strategy (DFID, 1999). For shrimp farmers, social capital was measured through neighbor relationship (S1), the degree of frequency of accessing information (S2), distance to the nearest relatives (S3), and taking part in community activities (S4).

The normalised value of the neighbor relationship (S1) was over 0.6 for all shrimp-farming methods. The shrimp farmers almost reported that they have a very good and good relationship with their neighbors with 37.3% and 35.6% respectively. The remainder have an acceptable relationship with each other, and the lower medium accounted for a small percentage (Table 2.6). With good relationships, the farmers would benefit from neighbors' willingness to help, sharing their experiences or benefitting from their support in some cases. Although you would not get any material support, you would feel good that someone else advocates or stands behind you. Based on the traditional culture of Vietnam, the relationship between neighbors is always friendly. In fact, approximately all of the shrimp farmers are ready to help and share experiences with their neighbors. The relationship with relatives (S3) also plays an important role in shrimp farming. Because relatives (parents, siblings, cousins) could lend a hand in difficult situations in terms of finances and encouragement. Therefore, living close to relatives is an advantage. And the survey revealed that shrimp families living within a radius of 10km was 36%. The average distance to their nearest relatives was 28km, and those living further than the average distance only accounted for 21% of the total. Hence, the normalised value of distance to the nearest relatives was pretty high, from 0.914 for the all shrimp farming households (Table 2.6).

Getting news on a daily basis (S2) also plays a vital role in shrimp farming such as keeping up with weather news, season crop incentives, fluctuation of shrimp prices, and so on. Without that information, it is easy to make bad decisions. The study recorded that almost all shrimp farmers had access to information through television. Twenty-three percent of households were updated with news every day, and more than 30% got the news regularly; farmers who rarely or never got updated news was a tiny percentage (Table 2.6). The scheme of shrimp crop was informed by local authorities in order to assure that every farmer begins a new crop at the same time. This action helps control disease spread because it is also based on the climate conditions suitable for shrimp farming. The intensive and semi-intensive farmers are especially concerned with this issue strictly because of the high density of shrimp stocking and high sensitivity to weather changes. In contrast, the extensive farmer paid less attention to obtaining that information because of its particular characteristics, such as low density and year-round stocking. Therefore, the normalised value of this indicator was the highest for intensive shrimp farming and the lowest for the extensive farming (Table 2.6).

A majority of shrimp farmers did not take part in community activities (92%) which comprise festivals and sport clubs. Hence, the normalised value of taking part in community activities was very low for all the farming methods. Despite those activities prevailing in each local area, only children and people who do not work take part in them. Shrimp farmers are busy with their shrimp ponds, although they have occasional meetings and share experiences, building a close relationship with the community. The farmers need a practical activity such as a shrimp farmer club where they can meet weekly or monthly to discuss technical problems related to shrimp farming. Nearly 60% of surveyed shrimp farmers agreed to establish a shrimp farmer club.

With the advantage of living close to relatives, having a good relationship with neighbors and frequently access information but rarely attend local community activities: as a result, the value of social capital was highest for intensive farming and lowest for extensive farming (Fig. 2.1).

**Table 2.6. Statistic values of indicators of social capital**

| Indicator | Scale | Percent | Intensive | Semi-intensive | Extensive |
|---|---|---|---|---|---|
| Neighbor relationship (S1) | Very good | 37.33% | 0.721 | 0.608 | 0.643 |
| | Good | 35.67% | | | |
| | Medium | 22.67% | | | |
| | Lower medium | 4.33% | | | |
| | Very bad | 0% | | | |
| Degree of frequency of access to information (S2) | Every day | 23.33% | 0.756 | 0.577 | 0.238 |
| | Regularly | 30.67% | | | |
| | Sometime | 31.67% | | | |
| | Rarely | 9.33% | | | |
| | Never | 5% | | | |

| | | | | | |
|---|---|---|---|---|---|
| Distance to nearest relatives (S3) | Within 10km<br>Within 20km<br>Within 30km<br>Over 30km | 36%<br>57%<br>79%<br>21% | 0.920 | 0.914 | 0.945 |
| Taking part in community activity (S4) | Yes<br>No | 8%<br>92% | 0.041 | 0.145 | 0.233 |
| **Normalised value of social capital** | | | **0.610** | **0.561** | **0.515** |

**Financial capital**

Financial capital encompasses all kinds of tangible property which can be liquidated into cash. Those financial resources are allocated for investment with an aim to achieve livelihood objectives (DFID, 1999). For shrimp farming, financial resources play a very important role that determines whether a farmer can continue farming in case of crop losses or investments needed to adapt to severe climate change conditions.

In this study, financial capital refers to having access to bank loans (F1), credit from relatives (F2), having a savings account (F3), and annual income from shrimp farming per capita (F4). The recorded data shows that 72% of shrimp farmers could not access bank loans (Table 2.7). Most of the households that had an area of less than 2ha (Table 2.4) were those of intensive and semi-intensive shrimp farmers who needed more money to invest in facilities and equipment for cultivating. However, they found it difficult to access credit from the banks due to the low value of their farmland. And as a result of the normalised value, the bank's offerings of credit were dramatically low for extensive farming.

In terms of credit for shrimp farming, besides bank credit, the study recorded that 10% of households were borrowing money from their relatives. An advantage of this approach is that it is based on prestige or trust rather than the value of mortgage property. However, intensive shrimp farming did not take full advantage of this credit, while 18.6% and 16% of the extensive and semi-intensive farmers, respectively, could access credit from relatives. By contrast, more than 70% of intensive and semi-intensive households had a savings account, while approximately 50% of the extensive households had one. Holding a savings account would be considered a safety net in adverse financial situations whether these scenarios involve reinvesting in shrimp farming, an ill family member, or school fees for children. Although the annual income from shrimp farming per capita was under 25 million VND and accounted for 51.3% of shrimp farmers, a large proportion of shrimp-farmer households saved large amounts of money for financially trying situations. Consequently, the normalised value of the savings account indicator was relatively high for the three shrimp farming methods.

The survey reported that the annual income of individuals was approximately 35 million VND. There were only 15.3% of households with an annual income per capita of over 50 million VND (Table 2.7). The annual income was calculated from shrimp-farming earnings after deducting all costs for the shrimp crops and not yet considering the household's expenditures. The study uses income per capita as an effective indicator to measure the financial capital because the productivity from shrimp farming varies between intensive, semi-intensive, and extensive farming. Although the shrimp productivity per hectare of extensive farming is the lowest, its farm size is largest among three shrimp farming methods. The average farm size was 5.7 ha for extensive farming, 2.6ha for semi-intensive farming, and just 0.3ha for intensive farming. Thus, the average annual income per capita for extensive farming, semi-intensive farming, and intensive farming was 41.7 million, 56.7 million, and 26 million VND, respectively. The normalised value of this indicator was lowest for intensive farming, which was approximately equal to half of the two other values.

In general, the normalised value of the financial capital of shrimp farmers in Tra Vinh province was very low (Table 2.7). They found it difficult to secure credit from both banks and relatives. Intensive farming is considered a high-profit farming model but with a high risk of spreading disease. Hence, its annual income per capita was lower than the other forms.

**Table 2.7. Statistic values of indicators of financial capital**

| Indicator | Scale | Percent | Intensive | Semi-intensive | Extensive |
|---|---|---|---|---|---|
| Access to bank loans (F1) | Access to bank loan | 28% | 0.292 | 0.339 | 0.140 |
| | No access | 72% | | | |
| Borrowing money from relatives (F2) | Yes | 10% | 0.097 | 0.161 | 0.186 |
| | No | 90% | | | |
| Having a savings account (F3) | Yes | 72% | 0.749 | 0.726 | 0.488 |
| | No | 28% | | | |

| | | | | | |
|---|---|---|---|---|---|
| Annual income from shrimp farming per capita (F4) | under 25 million VND | 51.30% | 0.108 | 0.265 | 0.188 |
| | from 25 to 50 million VND | 33.40% | | | |
| | from 50 to 200 million VND | 15.30% | | | |
| **Normalised value of financial capital** | | | **0.312** | **0.373** | **0.268** |

As analysed above, Fig. 2.1 shows that shrimp farmers' livelihood assets were lower than the mean value in terms of financial and human capitals. The three remaining capitals were just higher than the mean value but under a good point (0.7). The overall values of livelihood assets were ranked in order from the highest to the lowest for semi-intensive, intensive, and extensive farmers, respectively. Semi-intensive farmers had more financial and natural capital than the farmers of other systems. In contrast, the intensive farmers had the highest values for social and physical capital. And the extensive farmers' livelihood assets were the lowest of all, except for their physical capital.

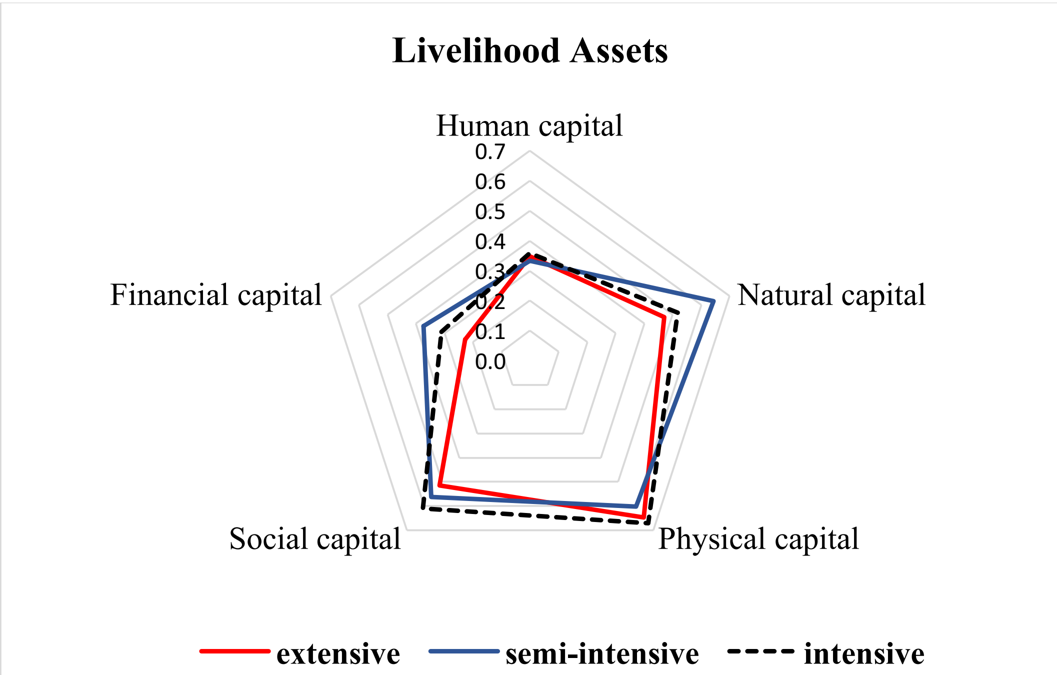


**Figure 2.1 Current status of five livelihood assets of shrimp farmers classified by shrimp farming method in Tra Vinh province.**

### 2.3.2 The effect of livelihood assets on the environmental sustainability of shrimp farming

In this study, the dependent variable is the environmental sustainability of shrimp farming (Env_sus) measured by the list of 19 criteria (Table 2.8). Those chosen criteria are based on the research in studies such as Manoj et al. (2009), Valenti et al. (2011), Chowdhury et al. (2015), and Roennback (2002). The Vietnamese environmental laws are also taken into account as well as other expert opinions.

**Table 2.8. The list of criteria for environmental sustainability of shrimp farming in Tra Vinh province**

| # | Criteria | Response (%), N=300 | |
|---|---|---|---|
| | | **Yes** | **No** |
| 1 | Treatment of input water | 86% | 14% |
| 2 | Treatment of wastewater (effluent water) | 60% | 40% |
| 3 | No use of groundwater in shrimp farming | 36% | 64% |
| 4 | Developing the shrimp farms in low salinity to minimise the risk of salinisation of adjacent soil and water | 100% | 0% |
| 5 | Having an environmental certification in shrimp farming | 0% | 100% |
| 6 | Building sluice gates and dikes to protect saline water intrusion or flood | 83% | 17% |
| 7 | Benefits by having government-managed water flow | 86% | 14% |
| 8 | Access to electricity power | 100% | 0% |
| 9 | Access to path or street directly for transport. | 100% | 0% |
| 10 | Taking part in shrimp production training courses | 60% | 40% |
| 11 | Using culture system that utilises natural or stimulated production in ponds or incoming water | 35% | 65% |
| 12 | Using formulated food from prestigious suppliers | 100% | 0% |
| 13 | Having land used for pumping sludge from the ponds | 80% | 20% |
| 14 | Does not use pesticides that kills wild crustaceans | 82% | 18% |

| | | | |
|---|---|---|---|
| 15 | Using chemicals to treat water in pond under strict official regulations (only use permitted chemicals) | 100% | 0% |
| 16 | Use medicines (antibiotics) to remedy shrimp diseases under strict official regulations | 100% | 0% |
| 17 | No substances used to stimulate shrimp growth | 99% | 1% |
| 18 | Use seed from the local prestigious hatchery suppliers | 67% | 33% |
| 19 | There are always available buyers | 100% | 0% |

To preserve the shrimp-farming environment, the farmers have to control both input and output water under the technical and environmental laws. To satisfy the technical aspect, proper input water treatment is required to meet the quality standard for shrimp farming. However, using chemical substances to treat water and using medicine remedies to cure shrimp diseases have to be compliant with regulations. All illegal chemicals or abusing legal chemicals would do more harm than good to the environment surrounding shrimp farms. The permitted chemical to treat input water is usually chlorine, BKC (benzalkonium chloride), or saponin to guarantee there are no wild aquatic species before shrimp-larvae cultivating. The data reported 86% of farmers treated the input water, but 18% use pesticides to kill wild crustacean due to the low costs involved or lack of knowledge of the harm it does to the environment, or both. One hundred percent of shrimp farms used chemicals to treat water in ponds under strict official regulations, and there were almost no farmers using substances to stimulate shrimp growth. Sixty percent of farmers were recorded as having treated discharge water. Discharge water contains pollutants, eutrophication, and residual chemicals that would be harmful to natural aquatic species, and they would pose a risk of spreading disease to adjacent farms. Hence, the treatment outlet is not only required by law, but it is also farmers' responsibility to common natural resource. In addition, to avoid accretion in rivers or canals due to solid sediment from shrimp ponds, shrimp farms must have enough land for pumping sludge from the ponds. The data showed that 80% of farms met this requirement.

Besides the technical requirement for building sluice gates, dikes must be reinforced to protect against seepage problems, floods, or sea-level rise in the context of climate change. Moreover, shrimp farms are located in areas planned by local authorities, which aims to minimise the risk of salinisation of adjacent land and water (Roennback, 2002; Decision 109/QD-UBND dated 18 January 2018). Brackish shrimp farming requires a salinity range of 15-25ppt (MOFI, 2006; Anh et al., 2010), which is not suitable for growing rice, fruit trees, or for vegetable growing. Therefore, all shrimp farms in Tra Vinh province are located in the planned areas run by local authorities. In the specialised locations, shrimp farms could receive the benefits of water management in the form of maintaining the right water levels of rivers or canals for each season. As a result, 86% of farmers were satisfied with this service. In addition, the planned farm areas have easy access to electricity and have the necessary power for lighting and aerator systems. Long ago, before farmers had electricity, they used diesel engines to operate the aerator system and the lights. The diesel engine is not only highly charged but also pollutes the environment with its fumes and leaking oils. Today, the government has brought a power approach to all the planned shrimp farms. They also must facilitate transportation of materials needed for farming or harvesting by building the convenient roads or paths to those areas.

In order to heighten farmers' sense of environmental responsibility, annual training courses are run by the local authorities (Table 2.9). For instance, the Preservation of Natural Sources course improved farmers' awareness of environmental protections. VietGAP (Vietnamese Good Aquaculture Practice) courses are especially good for not only helping shrimp farmers harvest the highest-quality shrimp but also for teaching farmers how to be environmentally conscious. Therefore, attending those courses would increase the environmental sustainability of shrimp farming. Although so far there is no farmer getting an environmental certificate, shrimp output can always be sold easily due to an abundance of available buyers. The study recorded just 60 percent of shrimp farmers concerned and took part in those courses, although the report of the Aquaculture Department of Tra Vinh province said that they have organised several training courses for shrimp farmers all over the province about environmentally sustainable shrimp farming. Some reasons the farmers gave for not being interested in those training courses were that it is difficult to apply what they learned, beyond their abilities, or they had no time to participate.

**Table 2.9. Training courses in the last five years**

| Course | Unit | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| Law applied in aquaculture activity | Class | 40 | 39 | 51 | 94 | 87 |
| | Participants | 1,069 | 1,080 | 2,280 | 3,053 | 3,425 |
| Good Aquaculture Practice of Vietnam (VietGAP) | Class | 99 | 40 | 52 | 21 | 0 |
| | Participants | 2,611 | 953 | 1,350 | 525 | 0 |
| Preservation natural aquatic resource | Class | 39 | 30 | 53 | 35 | Brochure |
| | Participants | 1,030 | 870 | 880 | 1,076 | 5,500 |
| Scientific meeting | Times | 4 | 4 | 6 | 0 | 0 |
| | Participants | 230 | 182 | 215 | 0 | 0 |
| Local broadcasting on television | Times | 4 | 4 | 16 | 9 | 12 |

*Source: Ministry of Agriculture and Rural Development- Aquaculture Department of Tra Vinh province. Annual Final Report of Aquaculture production of Tra Vinh province.*

Using groundwater in shrimp farming is considered environmentally unsustainable in the long term. The study reported 64% of shrimp households were pumping groundwater to supplement water during the harvest. Uses such as balancing pH degree, compensating for evaporated water, and exchange water for shrimp ponds were recorded. This extraction was involved in intensive (90%) and semi-intensive (27%) shrimp farming but not in extensive shrimp farming.

Groundwater exploitation is cited as the main cause of subsidence in the Mekong Delta. Its average rate of subsidence has been about 1.1 cm annually over the past 25 years; this trend is likely to increase in the near future (Minderhoud et al., 2017). Because the surface water is increasingly polluted and salinated, groundwater becomes an optimal choice for meeting the urgent demand (Wagner, et al., 2012). Hence, groundwater level and storage capacity are proposed to decrease gradually over the years, and salinisation of groundwater would exacerbate and expand (Vuong, 2014). Nowadays, surface water shortages and seawater intrusion prevails in the Mekong Delta, which accelerated groundwater exploitation in agriculture activities and aquaculture production. Furthermore, shrimp farmers used groundwater because of the polluted water resources and to avoid the risk of spreading disease.

The consequences of groundwater extraction are a grave concern of scientists and authorities in the context of climate change (Fig. 2.2). The study revealed that nearly 100% of shrimp farmers did not realize excessive groundwater extraction was the main factor leading to subsidence and seawater intrusion in the Mekong Delta in general. In fact, polluted water resources led to increased conflict among shrimp farmers. They realised that there would be risks when adding water to growing shrimp ponds if their neighbors are discharging water directly into rivers or canals without treatment. To protect themselves, groundwater was used as a short-term solution. Groundwater use for shrimp and fish farming is banned by Tra Vinh province's authority under Decision No. 19/2015/QD-UBND dated 10 August 2015. The enforcement of the law, however, is erratic because farmers claim to use groundwater for domestic purposes, or they stop pumping temporarily to avoid the scrutiny of authorities.

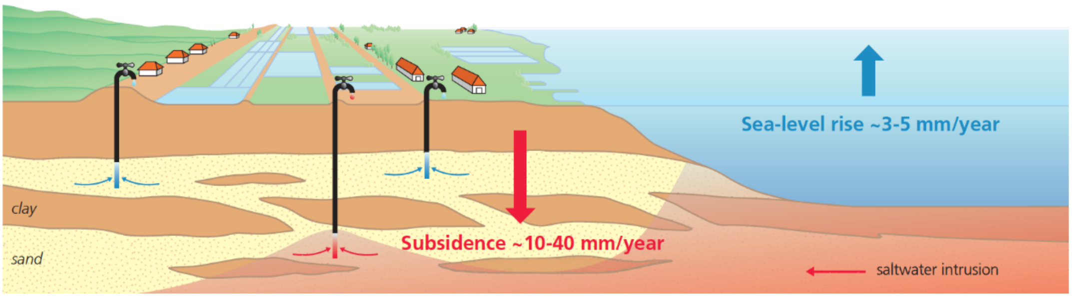


**Figure 2.2 Illustration of groundwater extraction**

*Source: Dr. E. Stouthamer, Prof. Dr. P. Hoekstra, Dr. G. Oude Essink, PhD, Minderhoud, MSc. and Dr. H. Otter. Utrecht University. Report from Rise and Fall research program.*

The environmental sustainability of shrimp farming is also related to the quality of the food which not only affects the shrimps' health but also reduces the food conversion rate (FCR). Food waste is the main cause of a high concentration of nutrients and organic matter in the shrimp ponds. They in turn create harmful algal blooms, sulfide compounds, and oxygen depletion. The survey recorded all farmers using formulated food from the brand-name companies. However, to decrease the accumulation of sediments from the food waste, utilising natural or stimulated food in ponds is considered a positive attribute of shrimp farming. Today, bio-floc technology is very popular in shrimp farming in some countries such as Thailand, China, and India. In Vietnam, this system has been tried in recent years but has not been popular. The study reported 35% of shrimp farms—intensive, semi-intensive farming—stimulated natural food in the first phase of stocking, and extensive farming utilised natural food during this process as the main food resource.

The best approach is using seed from prestigious local hatcheries that have a certificate of being clear of post-larvae disease. In terms of environmental sustainability, this action helps prevent disease from spreading. According to provincial quarantine regulations, all imported seeds from outside provinces have to present a certificate showing non-diseased seeds or wait for the results of testing by the local quarantine agents. However, there are several cases that are not declared at the quarantine agents, which contributes to disease outbreaks. Therefore, using prestigious local seeds would enhance the environmental sustainability of shrimp farming. The data showed that 67% of shrimp farmers bought post-larvae from the local hatcheries.

Overall, the environmental sustainability of shrimp farming was measured by several criteria to guarantee a reliable calculation of the normalised value. As a result, the value of the *env_sus* was relatively higher than the mean point. The semi-intensive practice had the highest environmental sustainability, while the intensive was second, and the extensive farming approach had the lowest value of environmental sustainability (Table 2.10).

**Table 2.10. Statistic values of the dependent variable**

| **Env_sus** (Environmental sustainability of shrimp farming) | **Scale** | **Value** | **Intensive** | **Semi-intensive** | **Extensive** |
|---|---|---|---|---|---|
| | Min<br>Max | 0.632<br>0.947 | 0.779 | 0.851 | 0.652 |

The Stata MP version 14 was used to estimate the regressions (Appendix 2.B). And the results are presented in the Table 2.11.

**Table 2.11. The result of estimating five capitals affected the environmental sustainability of shrimp farming**

| **VARIABLES** | **env_sus** | **VARIABLES** | **env_sus** |
|---|---|---|---|
| Human_capital | 0.0913** | H1 (Household labour capacity) | 0.00944 |
| | (0.0435) | | (0.0241) |
| | | H2 (Household education level) | -0.0155 |
| | | | (0.0282) |

| | | | |
|---|---|---|---|
| | | H3 (Households' experience in shrimp farming) | 0.0374* |
| | | | (0.0206) |
| Natural_capital | 0.266*** | N1 (The quality of water resource) | 0.00268 |
| | (0.0278) | | (0.0130) |
| | | N2 (Distance to water resource) | 0.0265 |
| | | | (0.0447) |
| | | N3 (Reservation pond) | 0.0954*** |
| | | | (0.00760) |
| | | N4 (Farm size) | -0.115*** |
| | | | (0.0378) |
| Physical_capital | 0.0178 | P1 (Quality of house) | 0.00566 |
| | (0.0207) | | (0.0106) |
| | | P2 (Household assets) | -0.00955 |
| | | | (0.0156) |
| Social_capital | 0.0312 | S1 (Neighbour relationship) | -0.0170 |
| | (0.0314) | | (0.0116) |
| | | S2 (Degree of frequency of accessing information) | 0.0153 |
| | | | (0.0151) |
| | | S3 (Distance to nearest relatives) | 0.0206 |
| | | | (0.0318) |
| | | S4 (Taking part in community activities) | -0.0162 |
| | | | (0.0122) |
| Financial_capital | 0.127*** | F1 (Access to bank loans) | 0.0310*** |
| | (0.0289) | | (0.00855) |
| | | F2 (Borrowing money from relatives) | 0.0113 |
| | | | (0.0123) |
| | | F3 (Having a savings account) | -0.00294 |
| | | | (0.00877) |
| | | F4 (annual income from shrimp farming per capita) | 0.0764*** |
| | | | (0.0273) |
| Constant | 0.532*** | Constant | 0.658*** |
| | (0.0328) | | (0.0584) |
| Observations | 300 | Observations | 300 |
| R-squared | 0.2959 | R-squared | 0.4982 |

*Standard errors in parentheses*
**** p<0.01, ** p<0.05, * p<0.1*

The study carried out two regressions. The first regression was to find the relationship of five livelihood capitals to the environmental sustainability of shrimp farming (*env_sus*). The second regression consisted of seventeen explanatory variables which derive from the five capitals, with the *env_sus* as the dependent variable.

Table 2.11 shows that three out of five livelihood capitals have positive coefficients and statistical significance. The coefficient of multiple determinants ($R^2$) for *env_sus* is relatively low (0.296) which means that the *env_sus* was explained approximately 30% by the five livelihood capitals, while the second regression the *env_sus* was explained approximately 50% by 17 indicators. However, according to Gujarati (1995, p. 211), we should be more concerned about the logic or relevance of the explanatory variables to the dependent variables and whether they are statistically significant.

The human capital variable has a positive relationship with the *env_sus* at the significance of p-value < 0.01 in the first regression. Basing on DFID (1999) and expert opinions, in this study it uses three indicators to calculate its value (Appendix 2.A). In the second regression, the households' experience in shrimp farming (H3) variable was the only factor influencing the environmental sustainability of shrimp farming. It means that farmers who have more years of experience in shrimp farming act with more environmental responsibility. This is because over time, these farmers have recognized adverse changes in the environment.

The *env_sus* is dependent mainly on the natural capital with the highest coefficient value at a significance level of 1%. This implies that the *env_sus* would increase if the value of natural capital increases with the ceteris paribus assumption. In the second regression, the farm-size variable (N4) has a negative relationship with the *env_sus*. It indicates that households with larger farms tend to be responsible for more polluted water and face difficulties in farm management and disease control. Because wastewater from shrimp ponds discharges into the environment at an average of 28,330 to 37,930$m^3$/ha/crop (Anh et al., 2010) for intensive and semi-intensive farming, and 123 tons/ha/crop of sediment for a density of 25 post-larvae/$m^2$ (Manh and Nga, 2011). By contrast, the reservation pond (N3) variable has a significantly positive effect on the *env_sus*. To meet desirable farming standards continuously all year, even in the dry season when there is a scarcity of freshwater and more saltwater intrusion, the reservation pond is an effective way to confront those problems. The remaining independent variables such as quality of water resource (N1) and distance to water resource (N2) did not have a statistically significant impact on the *env_sus*.

The financial capital variable influences the *env_sus* somewhat positively, at a highly significant level of 1%. Two of four indicators have statistical significance at 1% and 5%. The remaining independent variables are not statistically significant because credit from relatives could not be an official and stable means of financing shirmp farming in the long term. Similarly, a savings account in households is usually used for family-related emergencies or school fees for children rather than reinvestment in shrimp farming. By contrast, annual income per capita (F4) and access to bank loans (F1) positively impact on the environmental sustainability of shrimp farming. It means that the higher the annual income per capita, the more environmentally sustainable shrimp farming is. This is because the successful people in shrimp farming have tended to be more concerned about environmental issues relating to their prospects. Furthermore, in the climate change context, the shrimp industry is facing more and more difficulties. Sufficient financial resources play an important role in investing in facilities and equipment to adapt to severe climate patterns: for example, installing more aeration systems in shrimp ponds to guarantee sufficient oxygen for shrimp, covering the plastic sheet at bottom of the pond to avoid being contaminated from soil; covering net over the pond to limit evaporation and infectious disease agents from the sky (birds eating shrimp). Besides annual income, having access to bank credit also increases the environmental sustainability of shrimp farming. Because the bank credit helps farmers overcome the bad financial situations like lost crop, or invest in the eco-environmental farming such as following the VietGAP standard.

### 2.4. Conclusion

The study showed that shrimp farmers in Tra Vinh province had moderate livelihood assets' values. The financial capital was a big problem for shrimp households. A majority of farmers found it difficult to access financial credits for investing in farming due to the small scale of farming and the low value of pledged land. In term of natural capital, they exposed some risk actions. Prevailing using groundwater in shrimp farming and have no reservation pond could not meet the conditions of sustainable shrimp farming.

The result of the first regression found that three livelihood assets had a positive effect on the environmental sustainability of shrimp farming, while physical capital and social capital had no statistical significance. And the second regression also stated that to avoid harm to the environment, using reservation ponds for treating water and storing water for shrimp farming are necessary for sustainable farming without compromising groundwater. Shrimp farmers should drop their short-term vision for a long-term outlook. Protection of the environment in shrimp farming is likely to ensure their future survival.

The limitations of this study are that some indicators of the forms of livelihood capital and a few criteria related to environmental sustainability of shrimp farming might be subjective and only pertain for shrimp farming in Tra Vinh province. And in this study, the sustainability of shrimp farming only encompasses the environmental aspect. While the overall picture of sustainability comprises three main pillars: economic, social, and environmental sustainability. However, the findings of this study contribute to the relationship between indicators of the livelihood assets and the environmental sustainability of shrimp farming in terms of quantitative method. The study should also inspire further research in general on the sustainability of shrimp farming and more specifically for each shrimp-farming production method.

Based on the findings, this study recommends a number of policy and solutions which are covered below.

**Improving environmental conception**

The authorities should continue to organize more frequent training courses for shrimp farmers and encourage them to discuss their current problems in order to come up with solutions. Besides the training courses, brochures about the environmental sustainability of shrimp farming and the standards for a certificate of quality as VietGAP, ASC and GlobalGAP should be given to every farmer. More publicity and media attention should be given to shrimp farming's successful families who abide by the environmental laws. There should be enhanced awareness of the impact of land subsidence and sea-level rise as a consequence of groundwater extraction.

**Mitigating pollution water resources and disease outbreaks**

To reduce diseases in shrimp farming, there should be sufficient attention paid to both ecological and technological approaches (Kautsky et al., 2000). The method of treating and recirculating water for shrimp farming is not still applied in Tra Vinh province. This method should be applied in order to prevent disease, and going forward less water should be used (closed system) in accordance with the environmental sustainability of shrimp farming. Replacing chemical substances in treating pond shrimp with biochemicals will help shrimp farming to become environmentally friendly. Biofloc in shrimp farming prevails in many countries such as Thailand, India, and China. The biofloc should be applied as a suitable solution for reducing the food conversion rate (FCR) as well as minimising polluted water resources.

Reforestation of mangroves alongside rivers and canals severely impacts shrimp-farming areas. These mangroves provide a natural filter, assimilating sediment, eutrophication, and plankton in the effluents from shrimp ponds (Barbier, 2016).

Reservation ponds are required for every shrimp-farming household as set out by the environmental law (Circular No. 27/2015/TT-BTNMT dated 29 May 2015). Controls are set on the process of shrimp farming by certifying farmers who meet the regulations of environmental protection.

Vietnamese authorities should enhance in monitoring of the environment in shrimp production areas to ensure farmers are obeying the regulations. There should be monetary incentives for anyone who submits evidence of untreated discharge water or groundwater being used for shrimp farming. A strict penalty should be implemented for such breaches.

Shrimp farmers should work together in communicating the time of discharge between farms in the same area. This action helps farmers' neighbours avoid pumping water at that time and could limit the risk of disease infection.

It is necessary to encourage university research and come up with effective vaccines for shrimp to make them disease resistant. Density of stock in shrimp farming should be decreased to a point where there would be a low risk of disease or easy to control quality water. It is better to maintain a healthy environment rather than pursue high profits with environmentally unsustainable results.

**Having access to financial credit**

While natural capital directly influences the environment and thus shrimp survival, financial capital is the important factor deciding the fate of shrimp farming in investing in new technologies adaptable to sustainable development. This study can offer some feasible suggestions for shrimp farmers trying to access credit. The goverment should provide a preferred interest credit programme for shrimp farmers. The combination of farmers and aquaculture exporting enterprises doing business through advanced payment contracts could act as a credit for farmers. This could create a bridge between banks and suppliers of food, facilities and equipment, and materials. It means the banks accept discounts on the deferred sale contracts from those suppliers. This is would be known as "deferred credit" for shrimp farmers.

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**Appendix 2.A. Indicators of Livelihood assets.**

| Indicators | Explanation of indicators | Survey question | Sources of indicators |
|---|---|---|---|
| **Human capital** | | | |
| Household labor capacity (H1) | If this indicator is high, the human capital would be strengthened.<br>Value of household labor capacity is calculated as follows:<br>A Non-labor =0 (including children too young to works, elder members too old to work, and disabled members cannot work)<br>A Semi-labor = 0.5 (including children and elder members who can do simple jobs in house or farming)<br>A Full- labor =1.0 (who are main members can do full time in farming activity)<br>The values of the labor capacity of all family members are summed up. Afterward, I normalized it by equation (1) | Please let us information about your family member labor and education degree. (this question is used for many related purposes, it contains a lot of information) | X. Hua et al., 2017 |
| Household education level (H2) | The education of each household was calculated by averaging the summing up all members' education of the family. Explicitly, each level education of member was assigned value such as: primary school = 6; secondary school =9; high | Please let us information about your family member labor and education degree. (this question is used for many related purposes, it | X.Hua et al., 2017; Huynh et al., 2018; Scoones 1998. |

| | | | |
|---|---|---|---|
| | school =12; college or university =16, non-education or illiterate = 0.<br>The values of the education level of all family members are summed up. Afterward, it was normalized by equation (1) | contains a lot of information) | |
| Household experience in shrimp farming (H3) | It assumed that a head of household with longer time shrimp farming would be more relative advantage of adaptive capacity of coping with climate change.<br>The indicator was calculated by number of year experience. | How many years do you experience shrimp farming? | From my experience and experts' opinions. |
| **Natural capital** | | | |
| The quality of river water resource (N1) | The quality of water resources affects directly shrimp farming. Although assessment of the quality of river water would be reliable and exact with the technical tests, just a result of this reflects merely at one point in time and at one of the places. The shrimp farmers who utilize this water directly and regularly, so they are able to realize how the quality of water is.<br>If a household said the water they are using in shrimp farming in polluted condition, they are risk at farming.<br>Similar to Lun Yang et al., (2018), the quality of cultivated land was considered as a natural capital indicator. Hence, the | What is water resource for shrimp farming like currently?<br><br>On scale from 1 to 5, where one means "definitely not polluted" and five means "very high polluted". | R. Pandey et al., 2012; Lun Yang et al., 2018. |

| | | | |
|---|---|---|---|
| | quality of water is suitable for the natural capital indicators in the case of shrimp farming.<br>Using a Likert scale to measure the indicator. | | |
| Distance to water resource (N2) | If the ponds are far away from river, households might find difficult to get or discharge water and bear more cost to do that. The indicator was measured by meter (m) | How far is it from your shrimp ponds to water resource? | C. Donohue, E. Biggs. 2015; Lun Yang et al., 2018. |
| Reservation pond (N3) | It is assumed that the reservation pond helps shrimp farmers treating water before shrimp cultivating, the way avoids the risk of casual agents from original river water. And treating discharged water from shrimp ponds as a conceptual environment that protects their livelihood activity in the future. Value assigned: Yes =1; No=0 | Do you have ponds for treating water-waste before discharging it into rivers? (reservation ponds) | Experts' opinions. |
| Farm size per capita (N4) | Real area ($m^2$) divided by family size | How is large shrimp farming area? ………… ($m^2$) | X. Hua et al., 2017, Experts' opinions. |
| **Physical capital** | | | |
| Quality of house (P1) | The quality of the house would help households feel safe and cope with extreme climate events. In the case of Mekong delta, a house is built by cement | What kind of your house?<br>1=cottage/ bungalow | X.Hua et al., 2017; Huynh et al., 2018; R. Pandey et al., 2017; |

| | | | |
|---|---|---|---|
| | and brick considered as a safe house with storms. | 2= cement level 4 (life span up to 30 years)<br>3= cement level 3 (life span up to 40 years)<br>4=cement level 2 (life span up to 70 years)<br>5=cement level 1 (life span up to 80 years) | |
| Household assets (P2) | The proportion of assets household-owned through a chosen list of assets (value from 0 to 1). | Please let us know what assets do you have?<br>(The list of ten assets for choosing) | Huynh et al., 2018; X. Hua et al., 2017; Lun Yang et al., 2018. |
| **Financial capital** | | | |
| Access to bank loans (F1) | Having access to bank loans is considered as an advantage in shrimp farming. Because it is said that the farmers could invest to extend the shrimp scale or improve some technology efficiently or go over difficulties in case of shrimp loss.<br>Value assigned:<br>From banks =1<br>Others =0 | Have you been borrowing money for shrimp farming? From who?<br>☐ From relatives<br>☐ Friends<br>☐ From banks<br>☐ Do not borrow | X. Hua et al., 2017; Lun Yang et al., 2018; Huynh et al., 2018 |
| Borrowing money from | It is similar to the bank loan, relatives-credit could support to the farmers. | Have you been borrowing money for shrimp | X. Hua et al., 2017; |

| | | | |
|---|---|---|---|
| relatives (F2) | Value assigned:<br>From relatives =1<br>Others =0 | farming? From who?<br>□ From relatives<br>□ Friends<br>□ From banks □ Do not borrow | Urothody et al., 2010 |
| Have a saving account (F3) | Having a saving account would be considered as a guarantee for bad financial situations. In the case of reinvesting shrimp farming or family members be ill or catastrophe.<br>Value assigned: Yes =1; No=0 | Do you have a saving account?<br>□ Yes □ No | Lun Yang et la., 2018; and Experts' opinions. |
| Average income from shrimp farming per capital (F4) | It is obviously a major income of shrimp farmers. This amount indicates the power of finance.<br>Real amount of money (million VND) | How much is average income from shrimp farming per year? ………….. (million) | X. Hua et al., 2017; Experts' opinions. |
| **Social capital** | | | |
| Neighbor relationship (S1) | Using a Likert scale of 5 degree to measure degree strong relationship with neighbor. | Please indicate what extent do you feel your relationship with neighbors?<br>① ② ③ ④ ⑤<br>On scale from 1 to 5, where one means "definitely bad" and five | R. Pandey et al., 2017; |

| | | | |
|---|---|---|---|
| | | means "definitely good". | |
| Degree of frequency of accessing information (S2) | Using a Likert scale of 5 degree to measure. (value from never=1, seldom=2, sometime=3, regularly=4, and every day=5)<br>Note: through media including internet, cell phone and television | How does your family have access to information through media?<br>① ② ③ ④ ⑤<br>On scale from 1 to 5, where value from never=1, seldom=2, sometime=3, regularly=4, and every day=5. | C.Donohue, E. Biggs, 2015. Experts' opinions. |
| Distance to nearest relatives (S3) | Living near relatives, higher opportunity to get help from them in case of hardship.<br>Real value (km) | How far is it from your house to the nearest relatives?<br>………. km | Experts' opinions. |
| Take part in community activities (S4) | Social activities are important to our life, especially in rural community. Attending to local community activity generate linking between farmers, enhance experience sharing chance. Advantage of social resource is to improve livelihood, which is usually in form of social networks or connections. (DFID, 1999).<br>Value assigned: Yes =1; No=0 | Do you take part in any community activity?<br>☐ Yes ☐ No | Experts' opinions. |

## Appendix 2.B Regression do-files

### Regresssion of Environmental sustainability of shrimp farming and five capitals

```
.reg env_sus Human_capital Natural_capital Physical_capital Social_capital
     Financial_capital


      Source |       SS           df       MS      Number of obs   =       300
-------------+----------------------------------   F(5, 294)       =     26.13
       Model |  .594264591         5  .118852918   Prob > F        =    0.0000
    Residual |  1.33713892       294  .004548092   R-squared       =    0.3077
-------------+----------------------------------   Adj R-squared   =    0.2959
       Total |  1.93140351       299  .006459544   Root MSE        =    .06744

------------------------------------------------------------------------------------
          env_sus |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------+-----------------------------------------------------------------
    Human_capital |    .091299   .0435198     2.10   0.037     .0056492    .1769488
  Natural_capital |   .2655336   .0277893     9.56   0.000     .2108424    .3202248
 Physical_capital |   .0177939    .020739     0.86   0.392    -.0230219    .0586096
   Social_capital |   .0311748   .0314469     0.99   0.322    -.0307148    .0930644
Financial_capital |   .1269732   .0288556     4.40   0.000     .0701835    .1837629
            _cons |   .5318952   .0328467    16.19   0.000     .4672507    .5965397
------------------------------------------------------------------------------------

. hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of env_sus

         chi2(1)      =     1.40
         Prob > chi2  =   0.2373

. vif

    Variable |       VIF       1/VIF
-------------+----------------------
Financial_~l |      1.05    0.954261
Natural_ca~l |      1.04    0.962175
Human_capi~l |      1.02    0.982652
Physical_c~l |      1.01    0.989430
Social_cap~l |      1.00    0.996949
-------------+----------------------
    Mean VIF |      1.02
```

### Regresssion of Environmental sustainability of shrimp farming and livelihood indicators

```
. reg env_sus H1 H2 H3 N1 N2 N3 N4 P1 P2 S1 S2 S3 S4 F1 F2 F3 F4

        Source |       SS           df       MS      Number of obs   =       300
-------------+----------------------------------   F(17, 282)      =     18.46
       Model |   1.0173615        17  .059844794   Prob > F        =    0.0000
    Residual |  .914042008       282  .003241284   R-squared       =    0.5267
-------------+----------------------------------   Adj R-squared   =    0.4982
       Total |  1.93140351       299  .006459544   Root MSE        =    .05693

------------------------------------------------------------------------------
     env_sus |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
```

```
          H1 |   .0094398    .024101     0.39   0.696    -.0380009    .0568804
          H2 |  -.0155422   .0282126    -0.55   0.582    -.0710761    .0399918
          H3 |   .0374345   .0206158     1.82   0.070    -.0031459    .0780149
          N1 |   .0026771   .0129957     0.21   0.837    -.0229037     .028258
          N2 |   .0265126   .0447233     0.59   0.554    -.0615213    .1145464
          N3 |   .0954066    .007604    12.55   0.000     .0804388    .1103745
          N4 |  -.1146832   .0377895    -3.03   0.003    -.1890685   -.0402979
          P1 |   .0056558   .0105598     0.54   0.593    -.0151304    .0264419
          P2 |  -.0095537   .0156005    -0.61   0.541    -.0402619    .0211546
          S1 |  -.0170212   .0116192    -1.46   0.144    -.0398926    .0058502
          S2 |   .0153227   .0151008     1.01   0.311     -.014402    .0450473
          S3 |   .0205795   .0317782     0.65   0.518    -.0419731     .083132
          S4 |  -.0162427   .0122061    -1.33   0.184    -.0402694     .007784
          F1 |   .0310174     .00855     3.63   0.000     .0141875    .0478472
          F2 |   .0112626   .0122975     0.92   0.361     -.012944    .0354692
          F3 |  -.0029438   .0087676    -0.34   0.737    -.0202021    .0143144
          F4 |   .0764037   .0272866     2.80   0.005     .0226924    .1301149
       _cons |   .6575974   .0583814    11.26   0.000     .5426789     .772516
------------------------------------------------------------------------------
```

**. hettest**

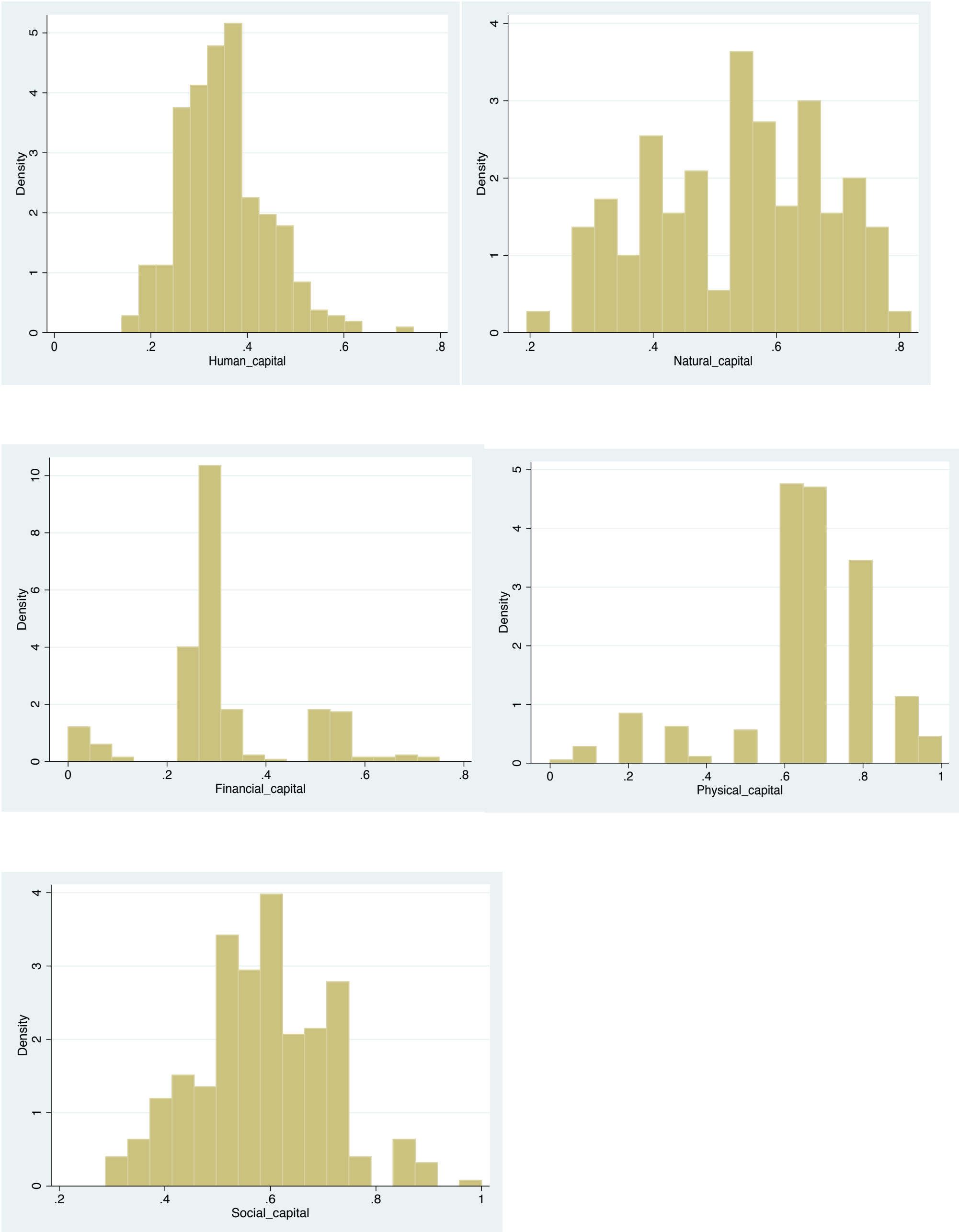
```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of env_sus

         chi2(1)      =     0.44
         Prob > chi2  =   0.5075
```

**. vif**

```
    Variable |       VIF       1/VIF
-------------+----------------------
          N4 |      2.24    0.445963
          S2 |      1.58    0.633351
          F4 |      1.45    0.688251
          F3 |      1.43    0.697178
          F1 |      1.36    0.733124
          N3 |      1.29    0.774412
          H2 |      1.27    0.786450
          F2 |      1.22    0.818155
          H1 |      1.14    0.877540
          S4 |      1.13    0.885431
          N2 |      1.12    0.896459
          N1 |      1.10    0.907898
          H3 |      1.10    0.911251
          P2 |      1.09    0.919249
          S1 |      1.07    0.935716
          S3 |      1.04    0.961341
          P1 |      1.04    0.964190
-------------+----------------------
    Mean VIF |      1.27
```

## Histograms of five capital variables



# Chapter 3: Analysing the livelihood vulnerability of shrimp farmers to climate change: A case study in Tra Vinh province, Vietnam

**Abstract**

This study measured the livelihood vulnerability index of shrimp farmers to evaluate their vulnerability to climate change by comparing three shrimp farming systems in Tra Vinh province, Vietnam. The analysis is based on the IPCC's framework of vulnerability assessment and uses three contributory factors – exposure, sensitivity, and adaptive capacity. Forty-two indicators were assessed for the three dimensions and five types of livelihood capital (human, physical, natural, social, and financial) under the Sustainable Livelihood Framework of Chambers and Conway (1992). A survey was carried out with 300 households, of which 195 engaged in intensive, 62 in semi-intensive, and 43 in extensive shrimp farming. In general, results indicated that shrimp farmers were vulnerable to climate change at a medium level, with the extensive system being the most vulnerable. Households engaged in semi-intensive shrimp farming had the lowest level of vulnerability. The intensive farming system was the most vulnerable to climate change in terms of natural, social and financial capitals while the extensive system was most vulnerable in terms of human and physical capitals.

## 3.1 Introduction

In Vietnam, the brackish-water shrimp farming industry has brought large profits to farmers in recent years. The industry has been developing since 1980 (MARD, 2015), and shrimp aquaculture now takes place from the north to the south of Vietnam, especially in the Mekong Delta where shrimp farmland accounted for 91% (699,725 hectares) of the total in 2014, with an average growth rate of 3.12% per year from 2010 to 2014. The Mekong Delta industry produced 661,074 tons of shrimp in 2014, equivalent to 80.61% of the total national production, a 1.5-fold increase compared to 2010 (MARD, 2015). Tra Vinh province is one of the 12 provinces in Mekong Delta suitable for brackish-water shrimp cultivation with its 65-km coastline and a dense network of rivers and canals. According to the

Department of Natural Resources and Environment of Tra Vinh province, its canal system includes 110 level 1 canals with a total length of 467 km, 690 level 2 canals with a total length of 2,110 km, and 8,800 level 3 canals with a length of 6,620 km. The authorities in Tra Vinh consider the shrimp industry to be a vital part of the economic strategy of the Province. By 2018, the shrimp farmland in Tra Vinh Province had expanded to 32,593 hectares and produced 52,778 tons of shrimp (Aquaculture Department of Tra Vinh). In addition, the Tra Vinh provincial authority's Decision 784/QD-UBND of 27 April 2018, 'Developing the shrimp farming industry to 2025', has plans to develop shrimp production based on each natural area of the Province: intensive and semi-intensive shrimp cultivation should continually develop and apply new technologies without abusing chemicals and antibiotics to acquire eco-environmental certification to meet the requirements of export markets, whereas extensive shrimp farming should consolidate and maintain production to preserve the existing mangrove forest and to balance the ecosystem.

However, in the context of climate change, the shrimp farming industry has suffered significant damage and loss in recent years. In 2018, the Aquaculture Department of Tra Vinh Province reported that 4,330 shrimp farming households had suffered damage to 1,550 ha of shrimp farmland due to drought, fluctuation in temperature, and epidemic disease. Adverse environmental factors and climate change have caused difficulties for the industry. From 1970 to 2007, the average temperature increased by 0.6 °C and average precipitation increased by more than 94 mm per year (MARD, 2015). By 2100, according to the A2 scenario of the Intergovernmental Panel on Climate Change (IPCC) of a 1-metre sea level rise (SLR), 85% of the Mekong Delta area (12,376 $km^2$) would be submerged. Tra Vinh Province, in particular, would lose up to 45.7% of the natural land area, and coastal land for aquaculture farming would totally disappear (Carew-Reid, 2007). Accompanying SLR, the average temperature is also estimated to increase by about 3 °C which will affect almost all economic areas, and shrimp farming in particular, by 2100 (MORE, 2008). According to the IPCC's A2 scenario, the rainfall in this area would increase by about 3% and 7% by 2050 and 2100, respectively; therefore, Tra Vinh province is predicted to experience more rainfall in the future, with the rain focused especially on coastal areas which are regarded as the most suitable for shrimp farming (JICA, 2013).

Aquaculture is vulnerable to climate change. Changes in climate causing higher temperatures, prolonged drought, heavy rain, and seawater intrusion inevitably result in reductions in desirable shrimp yields. In addition, these harsh conditions encourage the growth of harmful microbes whose proliferation can cause epidemics in shrimp farms. This in turn would lead to shrimp farmers increasing their use of uncontrolled chemicals and drugs to treat water and shrimp diseases. The poor quality of water in shrimp farms stems from this and whatever waste is discharged into the environment by the farmers is likely to return in the form of a disease sooner or later (Nyan Taw, aquaculturealliance.org).

Climate change will inevitably pose challenges to the productivity of shrimp farming. Thus, this study aims to (1) analyse the livelihood vulnerability index (LVI) under the IPCC's climate change scenarios, (2) assess the differences in livelihood vulnerability between three shrimp production systems, and (3) identify suitable solutions to decrease the vulnerability of each method of shrimp production to climate change.

## 3.2 Literature Review and Methodology

### 3.2.1 Literature review

The shrimp farming industry in Vietnam has three prevailing methods of production: intensive, semi-intensive, and extensive. The key features of each method are shown in Table 3.1. Intensive shrimp farming has been the predominant method of production in recent years. It only accounts for 1.8% of shrimp farmland, but it makes up 21.1% of the national shrimp output (JICA, 2013). In Tra Vinh province in particular, the intensive method accounted for 13.6% of the area under shrimp cultivation and 89.37% of the output in 2018 (Appendix 3.C). Under intensive farming, the shrimp are fed wholly on commercial food and are kept at a high stocking density of post-larvae, in the case of *Penaeus monodon* (black tiger shrimp) at 15–30 post-larvae/$m^2$ and *Litopenaeus vannamei* (whiteleg shrimp) at 40–100 post-larvae/$m^2$. Thus, the average production of the intensive system is higher than that of the other two methods. However, it requires a large capital investment. Therefore, intensive shrimp farming is practised by households with adequate financial capacity and an average farm size of 1–6 ha and by corporate farms 10–100 ha in size.

Semi-intensive shrimp farming is similar to intensive farming in terms of pond size, facilities, and the equipment used. However, farmers use fertiliser to generate some natural food for the shrimp and combine it with outsourced food such as small shellfish or molluscs, but the shrimp are fed mostly on commercial food. The density of seeding in this system is lower than that of intensive shrimp farming. It accounts for 8.2% of shrimp farmland, and makes up 35% of the national shrimp output (JICA, 2013). In Tra Vinh province, the Aquaculture Department reported that 1.35% of the shrimp farmland is under the semi-intensive system, generating 1.2% of the output in 2018.

Extensive shrimp farming is the most popular method of shrimp production in Vietnam, accounting for 90% of shrimp farmland, but only 43% of the national shrimp output (JICA, 2013). These numbers are quite different in Tra Vinh where 85% of the farming area was under extensive shrimp cultivation and produced approximately 9.4% of the output in 2018 (data from the Aquaculture Department of Tra Vinh province). Extensive shrimp farms are usually located in coastal areas where there are mangrove forests rich in natural food. Because of the low stocking density of only 5–7 post-larvae/m$^2$, stock is added regularly due to partial harvesting every month. The annual production average is only about 450–500kg/ha. The shrimp rely on natural food entirely, which makes this system suitable for famers who have low financial capability or do not have access to bank credit. Normally, farmers cultivate shrimp together with other aquaculture species such as crab and fish in order to improve their incomes.

**Table 3.1. Comparison of three shrimp farming systems in Vietnam.**

| **Key feature** | **Intensive shrimp farming** | **Semi-intensive shrimp farming** | **Extensive shrimp farming** |
|---|---|---|---|
| Pond size | 0.1–0.6 ha | 0.1–0.6 ha | 1–15ha |
| Average stocking density | 15–30 PL/m$^2$ (*P. monodon*)<br>40–100 PL/m$^2$ (*L. vannamei*) | 7–10 PL/m$^2$ (*P. monodon*)<br>20–50 PL/m$^2$ (*L. vannamei*) | 5–7 PL/m$^2$ (*P. monodon*) |
| Average production | 2–8 ton/ha (*P. monodon*)<br>6–15 ton/ha (*L. vannamei*) | 1–3 ton/ha (*P. monodon*)<br>3–9 ton/ha (*L. vannamei*) | 0.45–0.5 ton/ha (*P. monodon*) |

| | | | |
|---|---|---|---|
| Number of crops per year | 2–3 | 2–3 | Not clear distinction between crops |
| Type of farmer | Households and corporations | Households | Households |
| Treatment of effluents | Yes | Yes | No |
| Aeration system | Installed | Installed | None |
| Food | Commercial food | Commercial and natural food | Natural food |

Note: PL = post-larvae; *P. monodon* = *Penaeus monodon* (black tiger shrimp); *L. vannamei* = *Litopenaeus vannamei* (whiteleg shrimp)

Source: Hiep et al. (2016) and https://seafood-tip.com

**Some definitions from the IPCC's Fourth Assessment Report**

Climate change vulnerability is 'the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity'. The definition has four components – exposure, sensitivity, potential impact, and adaptive capacity – that affect the extent to which a system is susceptible to climate change (Adelphi/EURAC, 2014; Figure 3.1).

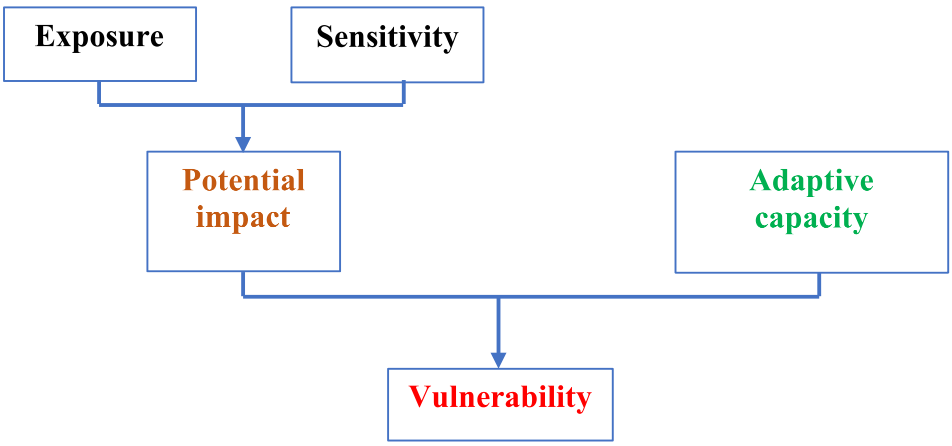



**Figure 3.1. Components of the vulnerability of a system to climate change.**

Sources: Allen Consulting (2005); Adelphi/EURAC (2014); CSIR (2017).

Exposure is 'the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected'. Thus, exposure is the nature and magnitude of climate change-related factors, in direct and indirect forms, to which shrimp farming systems are exposed, such as high temperature which causes the spread of shrimp diseases and leads to crop losses, scarcity of water resources, groundwater extraction, etc.

Sensitivity is ‘the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. Climate-related stimuli encompass all the elements of climate change, including mean climate characteristics, climate variability, and the frequency and magnitude of extremes. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damage caused by an increase in the frequency of coastal flooding due to sea-level rise)’. Climate change could be reshaped and increase or decrease in magnitude in the future. Therefore, sensitivity to climate change could be expressed as adverse or beneficial responses to climate-related stimuli. In this study, all indicators of the sensitivity factor reflect adverse effects due to negative climate-related stimuli. The stimuli have a positive relationship with the vulnerability of the shrimp farming system, meaning higher sensitivity leads to greater vulnerability.

The combination of exposure and sensitivity is the potential impact of climate change on a system. Afterward, a system’s vulnerability is the result of the interaction between the potential impact on the system and its adaptive capacity (Allen Consulting, 2005; Adelphi/EURAC, 2014).

Adaptive capacity is ‘the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences’. Thus, the higher the adaptive capacity of a system is compared to its exposure and sensitivity, the less vulnerable it is to climate change (Fig. 3.2).

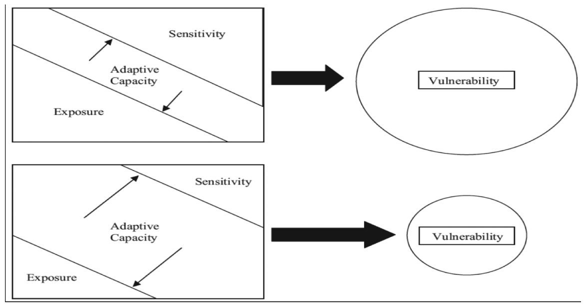



**Figure 3.2. The impact of adaptive capacity on the vulnerability of a system.**

Sources: Engle (2011); Fellmann (2012).

Vulnerability assessment has been mentioned in many international projects in relation to different aspects and fields. In order to aid populations that have suffered from the lack of staple food, multidimensional indicators have been employed to measure vulnerability (USAID, 2007a; World Food Programme, 2007). In the context of climate change and the emerging concern about how people could adapt to it, several studies have evaluated the vulnerability of households or communities to climate change. Hahn et al. (2009), Urothody et al. (2010), and R. Pandey et al. (2012) used seven components to calculate the livelihood vulnerability index (LVI) and LVI-IPCC (LVI incorporating the IPCC framework) at the village level. Based on the IPCC's (2001; 2007) theory of livelihood vulnerability, the seven IPCC components were grouped into the three dimensions, exposure, sensitivity and adaptive capacity, in accordance with the definition of vulnerability. The three dimensions were also measured based on the five forms of livelihood capital under the Sustainable Livelihood Framework of Chambers and Conway (1992), which was applied by R. Pandey et al. (2017) with the climate vulnerability index and current adaptive capacity index, and by Huynh et al. (2018) with LVI at the household level. However, the subjects of all these studies were households with a variety of livelihood strategies, in other words, households with different occupations. However, assessment of the vulnerability index at the village or community level does not provide an unbiased or complete picture. For example, heavy rain is not good for shrimp farming because it decreases the pH level of pond water causing stress to shrimp. However, it is good for rice or fruit farming. In this study, livelihood vulnerability assessment is carried out only for one occupation, i.e. shrimp farming.

### 3.2.2 Study area

Tra Vinh province is located in southern Vietnam at 9°31′46″–10°4′5″N and 105°57′16″–106°36′04″E (Fig. 3). It is one of 12 provinces in the Mekong Delta. Its topography is flat floodplain, with an elevation above sea level of approximately 1 m. It has a 65km long coastline. The province is subject to strong monsoons, a high rate of evaporation and relatively low annual precipitation. The average temperature ranges from 26 °C to 27.6 °C, and the average annual precipitation is about 1,520 mm. The area rarely experiences storms (e.g. Typhoon No. 5 in 1997 and Typhoon

Durian in 2006), but extended droughts frequently cause loss and damage to agriculture and aquaculture production (GSO–General Statistics Office of Vietnam).

Tra Vinh's dense network of rivers and canals has favoured the development of the shrimp farming industry across the whole province. This study was conducted in Duyen Hai and Cau Ngang districts which are two of the four most important shrimp farming regions in Tra Vinh province (Hiep et al., 2016). In 2018, the two districts accounted for 93.32% of the shrimp farming area and 89% of the productivity of the Province (Aquaculture Department of Tra Vinh province). The two districts were chosen as being representative of the shrimp farming industry in the province to calculate the LVI to climate change. Because they are coastal districts, they are susceptible to sea level rise, storms, and drought (791/QD-UBND, dated 7 April 2016).

Duyen Hai district (area 300.47 $km^2$) is located in the south of Tra Vinh province, and has a 55km coastline, 2,640 hectares of rivers and canals, with salinity ranging from 9‰ to 22‰ (Hydrological and Climatic Department of Tra Vinh province, 2018) which is within the optimal salinity range of 15–25‰ for shrimp farming (MOFI, 2016; Anh et al., 2010), and more than 100 hectares of coastal land. Its elevation is generally low and ranges from 0.4 m to 1.0 m above sea level. Duyen Hai was the first area to develop shrimp farming in Tra Vinh Province, adopting the mangrove shrimp farming model in 1990, and then semi-intensive and intensive models which emerged quickly. By 2001, the mangrove forest area had decreased dramatically, from 21,221 ha in 1965 to 12,796 ha (Thu et al., 2017).

Cau Ngang district (area about 325 $km^2$) is located in the southeast of Tra Vinh province, along the Co Chien river. Therefore, it is influenced by the tides of the East Sea through this river which is invaded by sea water in the dry season. It is difficult to plant crops (rice, corn, or watermelon) in this area, but the conditions are beneficial to aquaculture activities, especially shrimp farming. However, the salinity of the Co Chien river ranged from 0.1‰ to 8.1‰ over six months in 2018 (Hydrological and Climatic Department of Tra Vinh province, 2018). The district also has a 10km long coastline which favours fishing.

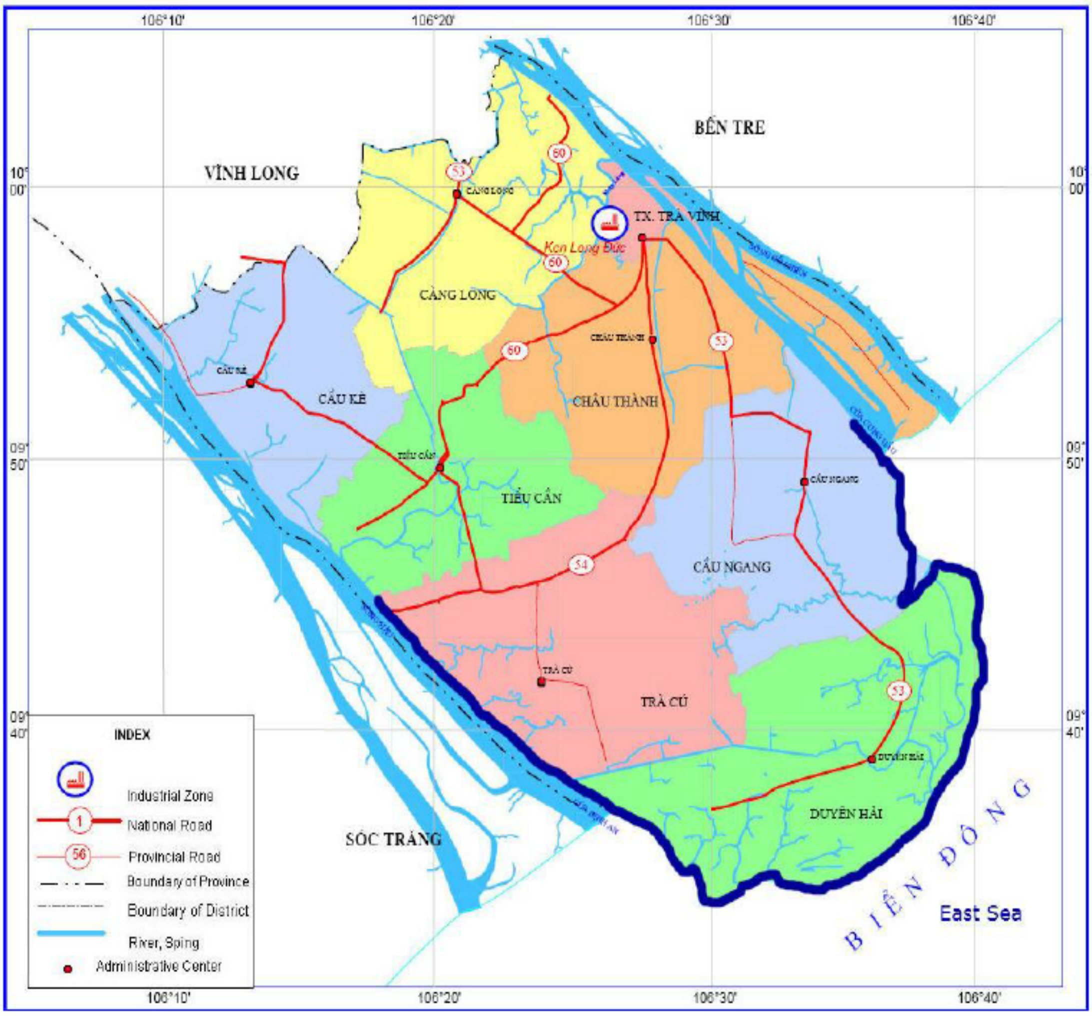



**Figure 3.3. Map of Tra Vinh province.**

Source: https://khongsolac.com/ban-do-du-lich-va-hanh-chinh-tinh-tra-vinh.html

### 3.2.3 Climate patterns and scenarios in Tra Vinh province

***Status of the climate in Tra Vinh***

Tra Vinh has 65 km of coastline, and a coastal tropical monsoon climate with a relatively high level of evaporation of 1,293 mm/year. Tra Vinh receives a high level of solar radiation; with an average temperature of 26 °C to 27.6 °C, drought adversely affects agriculture and aquaculture annually, with 10–18 days continuously without rain in the rainy season. The level of precipitation, at an average of 1,520 mm/year, is intermediate compared to the Mekong Delta. Figure3.4 shows the monthly average temperature and rainfall in 2013.

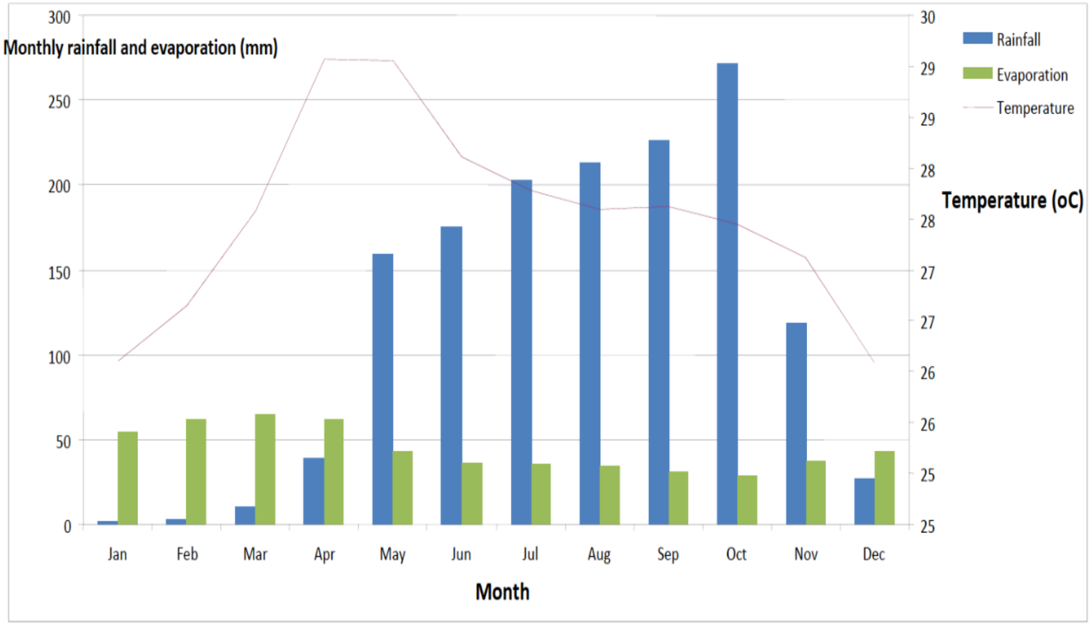



**Figure 3.4. Recorded climate patterns in Tra Vinh province in 2013.**

Source: Mai V.T et al. (2014).

***Climate scenarios for Tra Vinh province***

The IPCC's Fifth Assessment Report (AR5) used four representative concentration pathway scenarios for greenhouse gas emissions, RCP2.6, RCP4.5, RCP6.0, and RCP8.5, for modelling. In 2016, the Ministry of Natural Resources and Environment (MONRE) predicted climate change in Vietnam based on RCP 4.5 and RCP 8.5. Table 3.2 shows summary scenarios for predicted changes in average temperature, rainfall, sea level rise, and inundation for Tra Vinh province.

The RCP scenarios show that climate change will intensify in the 21$^{st}$ century. The RCP 4.5 scenario predicts that the average temperature would increase by 1.8 °C by the end of the century compared to the period 1986–2005, while the RCP 8.5 scenario estimates are likely to be double this increase (3.4 °C) for the same period. According to MORNE (2016), the RCP 4.5 scenario has a higher probability of occurrence than the RCP 8.5 scenario. Therefore, the government should base its actions on the RCP 4.5 scenario for short-term plans or programmes, and the RCP 8.5 scenario for longer-term and permanent plans or programmes. Similar to average temperature, rainfall is forecasted to be heavier under the RCP 8.5 scenario by the end of the century. In the 21$^{st}$ century, Vietnam is predicted to experience an average sea level rise of 55 cm (33–75cm) and 77 cm (51–106cm) under RCP 4.5 and RCP 8.5, respectively. Specifically, 1,873 ha of Tra Vinh would be inundated if the sea level rises by 50 cm, and 49,867.5 ha would be under water if the sea level rise is 100 cm.

The IPCC's Third (TAR) and Fourth (AR4) Assessment Reports specified six emissions scenario groups, A1FI, A1B, A1T, A2, B1, and B2 (IPCC, 2007). The MONRE (2016) and Mai et al. (2014) have projected temperature and rainfall by season for some of the scenarios for Tra Vinh province (Table 3.3).

**Table 3.2. Climate change scenarios according to the IPCC's Fifth Assessment Report (AR5) for Tra Vinh province[1].**

| **Scenario** | **RCP 4.5[2]** | | | **RCP 8.5[3]** | | |
|---|---|---|---|---|---|---|
| **Year** | 2016–2035 | 2046–2065 | 2080–2099 | 2016–2035 | 2046–2065 | 2080–2099 |
| Average temperature (°C) | 0.7 (0.4–1.2) | 1.4 (1.0–2.0) | 1.8 (1.2–2.6) | 0.8 (0.6–1.2) | 1.9 (1.4–2.6) | 3.4 (2.7–4.5) |
| % rainfall | 10.9 (4.9–16.3) | 15.7 (5.7–26.8) | 17.7 (4.1–30.0) | 11.4 (5.6–17.5) | 14.6 (8.4–21.5) | 18.2 (9.0–28.2) |
| **The risk of inundation of Tra Vinh when sea level rises due to climate change** | | | | | | |
| Sea level rise | 50 cm | 60 cm | 70 cm | 80 cm | 90 cm | 100 cm |
| % inundation | 0.8 | 1.02 | 1.33 | 2.38 | 4.93 | 21.3 |
| (ha) Area inundated[4] | 1,872.96 | 2,388 | 3,113.8 | 5,572 | 11,542 | 49,867.5 |

Source: MONRE, 2016. Summary of Climate change and Sea level rise Scenarios in Vietnam.

Table 3.3 shows that the precipitation in Tra Vinh is projected to decline in the dry season (from December to May) but increase in the rainy season (from June to November). Similarly, the average temperature is forecasted to increase strongly in the autumn and winter, but increase slightly in the spring and summer. Overall, annual rainfall and average temperature will increase more and more in the future.

[1] *Baseline: 1986-2005*
[2] *The RCP 4.5 is equivalent to B of the IPCC's AR4*
[3] *The RCP 8.5 is equivalent to A1, FI of the IPCC's AR4*
[4] *Total area of Tra Vinh is 234,120 ha (GSO, 2019)*

**Table 3.3. Climate change scenarios based on the IPCC's Third and Fourth Assessment Reports for Tra Vinh province.**

| Season | B1 Scenario | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Temparature changes | | | | Rainfall (%) | | | |
| | 2020 | 2030 | 2040 | 2050 | 2020 | 2030 | 2040 | 2050 |
| Dec.-Feb. | 0.3 | 0.5 | 0.6 | 0.8 | -2.7 | -4.4 | -6.2 | -7.7 |
| Mar.-May | 0.4 | 0.6 | 0.8 | 0.9 | -2.6 | -3.6 | -5.8 | -7.2 |
| Jun.-Aug. | 0.5 | 0.7 | 0.9 | 1.1 | 0.3 | 0.5 | 0.6 | 0.8 |
| Sep.-Nov. | 0.5 | 0.6 | 0.9 | 1.2 | 2.6 | 3.8 | 5.0 | 6.3% |
| | B2 Scenario | | | | | | | |
| | Temparature changes | | | | Rainfall (%) | | | |
| | 2020 | 2030 | 2040 | 2050 | 2020 | 2030 | 2040 | 2050 |
| Dec.-Feb. | 0.3 | 0.5 | 0.6 | 0.8 | -3.0 | -4.4 | -6.2 | -8.1 |
| Mar.-May | 0.4 | 0.6 | 0.8 | 0.9 | -2.8 | -4.1 | -5.8 | -7.5 |
| Jun.-Aug. | 0.5 | 0.7 | 0.9 | 1.2 | 0.3 | 0.5 | 0.6 | 0.9 |
| Sep.-Nov. | 0.5 | 0.6 | 0.9 | 1.2 | 2.6 | 3.8 | 5.3 | 6.8 |
| | A2 Scenario | | | | | | | |
| | Temparature changes | | | | % Rainfall change | | | |
| | 2020 | 2030 | 2040 | 2050 | 2020 | 2030 | 2040 | 2050 |
| Dec.-Feb. | 0.3 | 0.5 | 0.7 | 0.8 | -3.3 | -4.5 | -5.9 | -7.4 |
| Mar.-May | 0.4 | 0.6 | 0.8 | 0.9 | -3.0 | -4.2 | -5.5 | -7.2 |
| Jun.-Aug. | 0.6 | 0.7 | 0.9 | 1.2 | 0.4 | 0.5 | 0.6 | 0.8 |
| Sep.-Nov. | 0.5 | 0.7 | 1 | 1.2 | 2.8 | 3.8 | 5.0 | 6.5 |

*Note: Baseline years are from 1989 to 1999.*

Source: Mai V.T et al. (2014).

**Review of the impacts of climate change on shrimp farming**

Shrimp production is susceptible to changes in climate. Under the scenarios mentioned above, the increasing trend in temperature would have adverse effects on shrimp farming. High or low temperature causes stress to shrimp, affects their immune system, and poses a high risk of disease (MARD, 2015). Increased rainfall causes the salinity and pH of the water to drop. This would easily result in shock to shrimp or even their death. Using regression analysis based on data collected from 1999 to 2012, MORNE studied the relationship between shrimp productivity (tons) and independent climatic variables, such as average temperature ($x_1$), annual rainfall ($x_2$), and typhoons ($x_3$). The function was $Y = 525.55 – 9.909x_1 – 0.113x_2 – 26.99x_3$, with $R^2 = 0.989$ at $p < 0.05$. Assuming other inputs remain unchanged, based on scenario B2, if the average temperature increases by 0.72 °C and annual precipitation by 1.54%, the national brackish-water shrimp production would decrease by approximately 24,550 tons. Shrimp production in Tra Vinh, in particular, would decrease by approximately 1,076 tons (deduced from 'General report of the planning for brackish shrimp farming in Mekong Delta by 2020 and vision toward 2030' [MARD, 2015]).

Furthermore, under the projected climate change scenarios, Kam et al. (2012) assessed the degree of impact on shrimp production (Table 3.4).

**Table 3.4. The degree of impact of climate change on shrimp production.**

| | **Temperature rise** | **Drier dry season** | **Wetter wet season** | **Sea level rise: flooding** | **Sea level rise: salinity intrusion** |
|---|---|---|---|---|---|
| Extensive shrimp farming | **High:** ponds are relatively shallower, with large surface area and limited circulation (aerators not used) | **High:** increased competition for freshwater supply to counteract salinisation of pond water due to salinity intrusion | **Medium:** additional water supply for ponds, but increase in wet season rainfall is minimal | **High**: in areas not protected by sea dikes and considering large pond size and longer perimeter | **High:** particularly in areas not protected from salinity intrusion |
| Semi-intensive/ intensive shrimp farming | **Medium to high:** depending on amount of organic debris and decomposing leftover feed | | | **Medium**: in areas not protected by sea dikes | |

Source: Kam et al. (2012).

According to Diep et al. (2015), Tra Vinh province is one of four provinces in the Mekong Delta that would be subject to inundation and salinisation, with 23,766 ha and 97,720 ha affected in 2030 and 2050, respectively. In 2004, a total of 15.67 ha of mangrove forest, shrimp farms, fruit-growing areas and residential areas were affected by inundation and salinity. Nguyen et al. (2020) also concluded that, among provinces in the Mekong Delta, Tra Vinh is one of the most vulnerable to salinity intrusion.

### 3.2.4 Household survey

In the survey in this study, 300 households in total were interviewed, of which 195 practised intensive shrimp farming, 62 semi-intensive farming and 43 extensive shrimp productions. The households were selected randomly by each member of the team who was assigned a certain number of households in each village. This survey process was repeated in other villages until a sufficient number of households were interviewed according to the survey plan. The interview team consisted of only two members, with each member having to complete four surveys per day. The survey period was from the beginning of December 2018 to the end of January 2019. Originally, 320 households were surveyed, but 20 were omitted due to incomplete or illogical responses to the survey.

### 3.2.5 Study methodology

This study calculated LVI based on the IPCC framework (LVI-IPCC) by selecting suitable indicators from the five livelihood assets in the context of climate change that have direct and indirect impacts on shrimp farmers' livelihoods. Livelihood vulnerability to climate change was measured for three dimensions: exposure, sensitivity, and adaptive capacity (IPCC, 2007; Hahn et al., 2009; R. Pandey et al., 2012, 2017; Adelphi/EURAC, 2014). Livelihood assets were based on the DFID framework which has five types of capital: human capital, natural capital, physical capital, social capital, and financial capital. Each vulnerability dimension was measured using some indicators for each type of livelihood capital mentioned above. A total of 42 indicators were employed to calculate LVI-IPCC, which were selected based on many publications, discussion with experts who have experience of the particular shrimp farming systems. However, some of the indicators were based on the subjective experience of the author and experts. Although these indicators are suitable for this study, it may be necessary to reassess them and change them in future studies. The indicators for each dimension are shown in Table 3.5, and a detailed explanation of each indicator is presented in Appendix 3.A.

Because each of the indicators was calculated in different units or at different scales, they first had to be normalised on a rating scale from 0 to 1 for equation (1) (Hahn et al., 2009; Vincent, K., 2004; Antwi-Agyei et al., 2012; UNDP, 2007; Urothody et al., 2010):

$$I_v = \frac{Sv - Smin}{Smax - Smin} \quad (1),$$

where $S_v$ is the average original value of the indicator for each technology (v =1, 2, 3, where 1 = intensive farming, 2 = semi-intensive farming, and 3 = extensive farming), Smin and Smax are the minimum and maximum value of the indicator for all samples, and $I_v$ is the normalised average value of the indicator for each technology.

Then, indicators were aggregated for each dimension of vulnerability ($M_v$) by averaging all its indicators (all $I_v$ values) using equation (2) (R. Pandey et al., 2017; Urothody et al., 2010; Hahn et al., 2009):

$$M_{vj} = \sum_{i=1}^{n} \left( \frac{I_{vji}}{n} \right) \quad (2),$$

where $M_{vj}$ is one of the indices for the dimension of vulnerability for each type of capital, $I_{vji}$ is calculated by equation (1), j is the $j^{th}$ vulnerable dimension of each type of livelihood capital (j = exposure, sensitivity, or adaptive capacity), i is the $i^{th}$ indicator for each dimension, v is the shrimp farming method (intensive, semi-intensive, or extensive), and n is the number of indicators in each dimension $j^{th}$.

For the purpose of simplification, equation (2) assumed that the weight of each indicator was equal, which means that every indicator in each vulnerability dimension has an equal degree of importance and influence. This approach has been employed by authors such as Eakin et al. (2008), Sulliva et al. (2002), R. Pandey et al. (2017), Urothody et al. (2010), and Hahn et al. (2009).

Equation (3) was used to calculate the *Potential impact* (PI) (Adelphi/EURAC, 2014):

$$PI = \frac{\text{Exposure} + \text{Sensitivity}}{2} \quad (3)$$

The LVI under the IPCC framework for each type of livelihood capital was calculated by equation (4) (Adelphi/EURAC, 2014):

$$\text{LVI-IPPC}_v = \frac{[PI + (1 - \text{Adaptive capacity})]}{2} \quad (4)$$

According to the definitions given above, the exposure and sensitivity dimensions have a positive relationship with vulnerability, which means that higher scores reflect greater vulnerability. In contrast, adaptive capacity has a negative relationship with vulnerability. To ensure a value range of 0 to 1 for the three components in terms of vulnerability, the value of adaptive capacity has to be the inverse (1 − Adaptive capacity) when aggregating LVI in equation (4)

(Adelphi/EURAC, 2014). In other words, vulnerability is the consequence of susceptibility to adverse effects and inability to adapt or cope (CSIR, 2017).

The value of LVI-IPCC$_v$ ranges from 0 to 1, where 0 means least vulnerable and 1 means most vulnerable. Equations (3) and (4) were repeated for each type of livelihood capital. The overall LVI-IPCC is an average of the five livelihood capitals' LVI. For aggregation of equations (3) and (4), a weighted arithmetic mean was applied using equal weights. Appendix 3.D shows how the above equations were used.

**Table 3.5. Indicators of vulnerability to climate change based on five forms of livelihood capital.**

| Livelihood asset | Dimension of vulnerability | Indicator |
|---|---|---|
| Human capital | Exposure | Percentage of households with insufficient food (HE1) |
| | | Percentage of households with poor health (HE2) |
| | | Percentage of households with children discontinuing schooling or unable to afford school (HE3) |
| | Sensitivity | Percentage of households with a disease due to climate factors (HS1) |
| | | Percentage of households far from hospital (HS2) |
| | | Percentage of households far from school (HS3) |
| | | Ratio of non-labour to the total number of household members (HS4) |
| | Adaptive capacity | Household labour capacity (HA1) |
| | | Household education level (HA2) |
| | | Number of years of experience (HA3) |
| | | Percentage of households taking part in training on shrimp farming (HA4) |
| | | Percentage of households keeping livestock and cultivating vegetables (self-sufficiency in food) (HA5) |
| Natural capital | Exposure | Percentage of households reporting diseases in shrimp due to climate in three recent years (NE1) |

| | | |
|---|---|---|
| | | Percentage of households extracting groundwater for shrimp farming (NE2) |
| | Sensitivity | Percentage of households reporting that river water is increasingly polluted (NS1)<br>Percentage of households reporting unusual diseases in farmed shrimp (NS2)<br>Percentage of households with shrimp pond far from the river (water resource) (NS3) |
| | Adaptive capacity | Percentage of households changing model of shrimp farming (from extensive to semi-intensive/intensive; from semi-intensive to intensive) (NA1)<br>Percentage of households changing shrimp farming time (NA2)<br>Percentage of households having reserve ponds (NA3) |
| Physical capital | Exposure | Percentage of households with house damaged due to climate (PE1)<br>Percentage of households with shrimp ponds damaged due to climate (PE2) |
| | Sensitivity | Percentage of households without access to electricity (PS1)<br>Percentage of households without access to piped water (PS2)<br>Percentage of households far from road (PS3) |
| | Adaptive capacity | Percentage of households with cement and brick house (PA) |
| Social capital | Exposure | Percentage of households without access to media information (SE1)<br>Percentage of households not visiting relatives for over three months (SE2)<br>Percentage of households not taking part in local community activities (SE3) |
| | Sensitivity | Percentage of households relying on television for entertainment (SS1) |

| | | |
|---|---|---|
| | | Percentage of households without mobile phone for communication (SS2) |
| | Adaptive capacity | Percentage of households with good relationship with neighbour (SA1)<br>Percentage of households sharing experiences with others (SA2)<br>Percentage of households living near their relatives (less than 10 km) (SA3) |
| Financial capital | Exposure | Percentage of households refused a loan by bank (FE1)<br>Percentage of households unable to afford to pay the loan (FE2)<br>Percentage of households with loss of the last shrimp crop (FE3) |
| | Sensitivity | Percentage of households with bank loans (FS1)<br>Percentage of households depending on shrimp farming as the only source of income (FS2) |
| | Adaptive capacity | Percentage of households owning land (FA1)<br>Percentage of households with savings account (FA2)<br>Percentage of households able to borrow money from relatives (FA3) |

### 3.3. Results and Discussion

#### 3.3.1 Human capital

The exposure dimension was aggregated by three indicators – the percentages of households with insufficient food, poor health, and unable to afford school for their children – reflecting the impact of climate change on human capital. Most households reported that they had sufficient food (HE1). As it is the local custom, every family had the same routine for meals with three meals per day on the whole. In addition, it was easy for the households to obtain three different kinds of food for each meal, which was facilitated by the flourishing natural resources (for example, wild fish in rivers or canals) and farmed livestock, such as fish, chickens, and ducks, and vegetables. This factor also enhanced households' capacity to adapt to climate change, with extensive farming households reporting a much higher rate of adaptive capacity (86%) than intensive (55%) and semi-intensive (60%) farming households (HA5; appendix 3.B). Because of the technologies adopted for production (Table 3.1), extensive farmers had more free time than the others for keeping livestock and cultivating vegetables to supplement their food supplies.

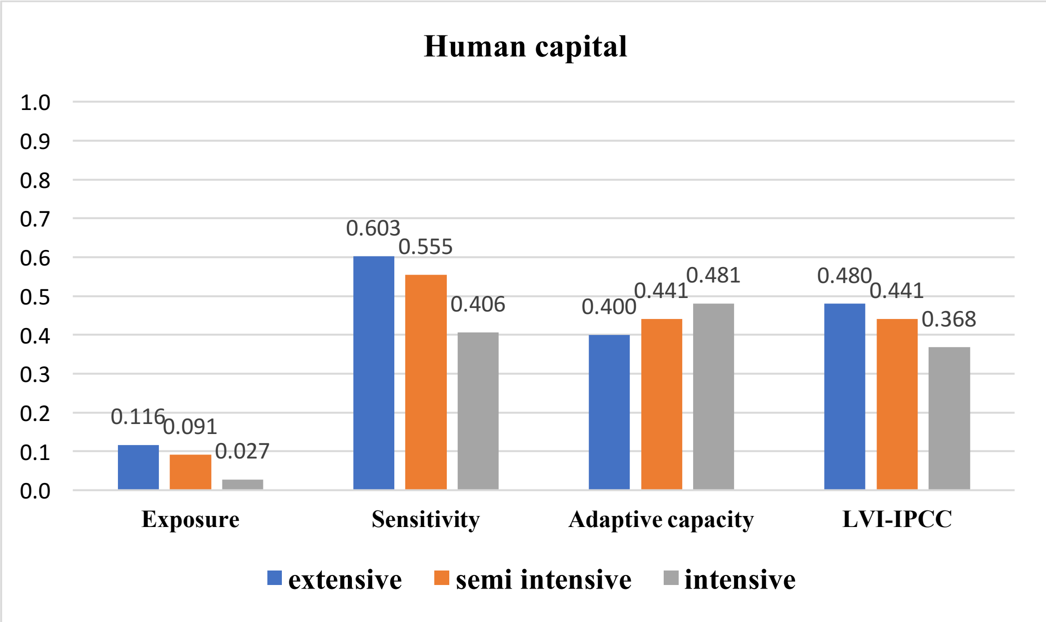



**Figure 3.5. Exposure, sensitivity and adaptive capacity of human capital in different shrimp farming systems.**

The percentages of semi-intensive and extensive farmers living far from hospital are nearly the same (HS2). According to the history of the shrimp farming industry, the extensive method was initially dependent on being located around the mangrove forest which is far from the centre of town, and the majority of semi-intensive farmers are those who decided to change the method of shrimp farming from extensive to semi-intensive. By contrast, intensive shrimp farming was developed later, and intensive farms are located in inland areas where there are rivers or canals and are closer the centre of town. This factor exacerbates the sensitivity problem, with higher percentages of households practising extensive or semi-intensive methods with illnesses (HS1) and poor health (HE2). Unsurprisingly, the data also showed a higher percentage of extensive and semi-intensive farming households living far from their children's schools than intensive households (HS3). Therefore, approximately 21% and 16% of children from extensive and semi-intensive farming households, respectively, discontinued schooling (HE3; appendix

3.B) while this was the case with almost zero percent of intensive farming households.

Therefore, respondents practising intensive shrimp farming reported almost no exposure to climate change at 0.027, whereas extensive and semi-intensive households showed slight exposure to climate change at 0.116 and 0.091, respectively (Fig. 3.5). The sensitivity dimension was also similar; it was lower for intensive farming households compared to extensive and semi-intensive households (Fig. 3.5).

Furthermore, the adaptive capacity index (to which five indicators contributed [Table 3.2]) of the intensive shrimp farming households was slightly higher than that of the others (Fig. 3.5). The main indicators that contributed to this result are the level of education of the household (HA2) and the percentage of households taking part in training (HA4). Both indicators were favourable to intensive shrimp farming (Appendix 3.B). Usually, the head of the household is the person who decides every important thing (Gilligan, 1982). However, the final decision is also based on ideas from all family members whose education has an influence on the livelihood strategy of the household. The level of education of households, therefore, is used to measure the capacity to adapt to climate vulnerability. Taking part in training courses brings many benefits, such as updated knowledge of shrimp cultivation, environmental responsibility in farming, and controlling and treating diseases. All of these increase the ability of shrimp farmers to adapt to climate change. This study found that the majority of intensive and semi-intensive farmers, more than 61% and 74% respectively, undertook training (appendix 3.B), whereas almost no extensive farmers participated in courses because of the simple technology they used for shrimp farming compared to the complex and high-risk farming of the intensive and semi-intensive methods. However, the survey also identified other key reasons for farmers not participating in these training courses, e.g. lack of time, difficulties in applying, or the courses not being innovative enough compared to their own experience. This suggests that local authorities should listen to farmers' feedback when designing suitable courses.

As a result of the three dimensions mentioned above, the LVI-IPCC of human capital was at a medium level, and was highest for extensive farming and lowest for intensive farming (Fig. 3.5) because extensive farming had the highest exposure and sensitivity but the lowest adaptive capacity while intensive farming showed completely the opposite results.

### 3.3.2 Natural capital

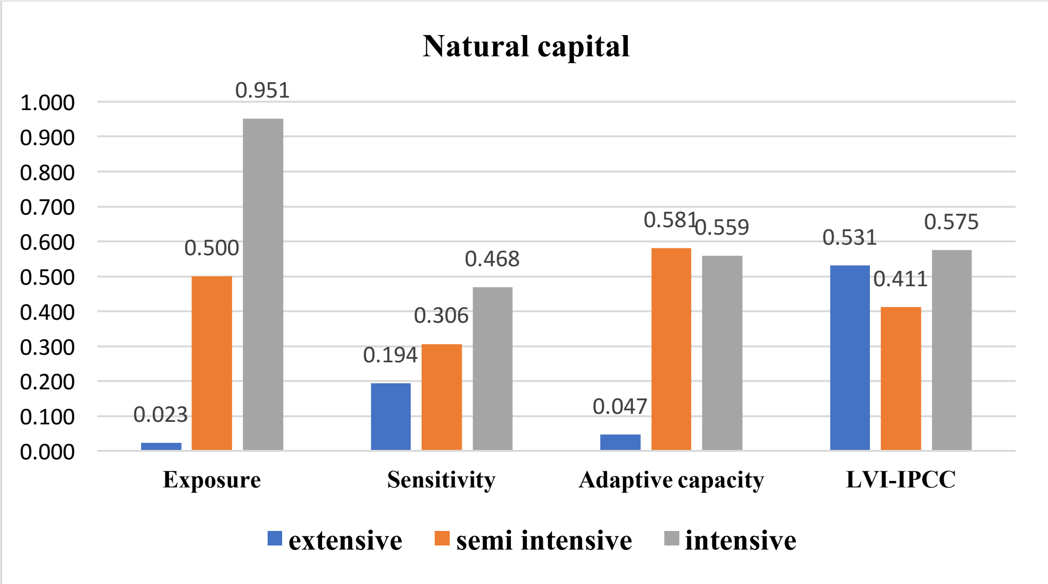



**Figure 3.6. Exposure, sensitivity, and adaptive capacity of natural capital in different shrimp farming systems.**

Natural resources play an important role in shrimp farming. The primary natural resource is water which is mainly drawn from rivers or small canals. The quality of water and its salinity, pH, and temperature are factors directly affecting the shrimp farming process. The status of water during the farming period is always a concern for shrimp farmers because of the need to respond quickly to adjust and balance the parameters of the water in ponds. Even minuscule changes in pH could be a big problem for the health of the shrimp. Polluted water or abrupt changes in water temperature could have a severe effect on shrimp. Therefore, effects of climate change and human behaviour on the natural environment, in turn, would lead to vulnerabilities in farming activity in general.

Fortunately, none of the shrimp farmers reported any unusual diseases in shrimp in the last three years (NS2). This indicator was included in the sensitivity dimension to reflect new hazards like diseases caused by climate change. Unusual diseases are regarded as an indirect result of climate change, and are assumed to be a factor causing vulnerabilities in shrimp farmers' livelihoods. However, the percentage of farmers reporting normal diseases in shrimp due to the climate (NE1) was considerable – 100% of intensive shrimp farmers and 72.6% of semi-intensive shrimp farmers over the past three years. By contrast, only 4.7% of the extensive shrimp farmers reported diseases in shrimp. The main factor that reduces the vulnerability to climate change of extensive production is the density of stocking (Table 3.1). Some normal diseases in shrimp farming, such as yellowhead disease, Taura syndrome virus, monodon baculovirus, white spot syndrome virus, and hepatopancreatic parvovirus were recorded. Although shrimp diseases have many direct and indirect causes such as the low quality of post-larvae, polluted water, and infection transmitted from other ponds, climate factors appear to exacerbate the situation.

The survey team recorded adverse climate patterns that can cause shock to shrimp, such as large differences in temperature between day and night, heavy rain, sudden rains in the dry season, and drought. According to Bui Quang Te (2003), shrimp are highly sensitive to temperature; a water temperature that is too high or too low is unfavourable for shrimp growth. The threshold water temperature for shrimp is 28–32 °C. There is evidence that although high temperatures stimulate shrimp to grow rapidly, they also make them highly susceptible to disease (Wyban et al., 1995). Therefore, temperature rise has both advantages and disadvantages. The metabolic rate of shrimp may increase when water temperature rises, which could promote digestion and enhance the growth rate. However, organic decomposition also increases with high water temperature, leading to the lowering of dissolved oxygen which is one of the main causes of mass die-off of shrimp (Kam et al., 2012).

Drought also led to another exposure indicator: extraction of groundwater (NE2) to compensate for water evaporation from ponds. Groundwater extraction is lower in cost than treatment with river water and may help to avoid the risk of diseases in river water. If water from shrimp ponds with disease is discharged into the river directly without any prior treatment, for someone else to charge their ponds with river water, even with thorough treatment before pumping the water, is a high-risk activity. In addition, water is added to ponds at the growing phase of shrimp, the most susceptible stage of production. Therefore, farmers are very careful in using river water if they are not able to control the quality of the water. This issue was highlighted by 90% of intensive farming households compared to 27.4% of semi-intensive farming households, which tend to use groundwater for supplying shrimp ponds. No extensive farming households identified this issue due to the lower density of seeding.

Furthermore, extraction of groundwater for cultivation of other crops as well as for shrimp farming is inevitable. In the dry season, the scarcity of freshwater is a serious problem. Many reserved water dams have been built upstream of the Mekong River (in China, Thailand, Laos, and Cambodia). Thus, downstream of the Mekong River, not enough water is available for cultivation in the Mekong Delta and seawater has invaded the Delta in recent years. In addition, groundwater has depleted by about 2–5 m in depth, which has forced farmers to drill deeper into the ground to find freshwater (the average depth of wells is about 15–20 m) (Cong, N.V, 2017). However, the sad fact is that most farmers realised that the volume of groundwater was decreasing only when asked about the consequences of extracting groundwater, and none of them had a conception of the accompanying land subsidence that would threaten their livelihoods and exacerbate the flooding caused by sea level rise in the foreseeable future. According to Erban et al. (2014), the average rate of land subsidence in the Mekong Delta is 1.6 cm per year, the main cause being groundwater extraction, with a recorded number of about 553,135 wells extracting approximately 1,923.681 $m^3$ per day in 2010 (Ha et al., 2015). However, farmers using this limited water resource still do not have any better strategies for the future. Groundwater use does not meet sustainable strategy for shrimp farming under the Sustainable Livelihood Framework (Chambers and Conway, 1992; DFID 1999)- sustainable livelihood strategy is the ability to cope with climate change by using available resources without overusing them by disregarding posterity. Groundwater extraction-induced subsidence is outpacing the global sea level rise, which raises significant concerns in the context of climate change.

Overall, intensive shrimp farming had the highest exposure (0.951), nearly double that of semi-intensive shrimp farming (0.5) while exposure was insignificant for the extensive method (0.023) (Fig. 3.6). Many factors cause shrimp disease, one of which is polluted water. In the survey, 85%, 63% and 39.5% of intensive, semi-intensive, and extensive shrimp farmers, respectively, agreed that the river water is currently polluted (NS1). The farmers' responses demonstrate the threat posed by polluted water to shrimp cultivation. In other words, polluted water resources add to the predicament of shrimp farmers in the context of climate change. Water pollution is caused by farming and other activities. First, when farmers discharge water from their ponds into rivers, it can contain pollutants as well as chemicals. For example, 1–1.5 tons of lime per ha used in shrimp farming (Anh et al., 2010), fertiliser, and large amounts of shrimp feed are discharged into the surrounding surface water. Second, there is no waste collection system in rural areas (no waste bins); hence, waste generated from farming and household activities, such as plastic bags and bottles, are burnt or buried, or in some cases thrown into the river, inevitably contributing to environmental pollution. According to the results of water quality tests carried out in 2012 (MARD, 2015), the pollution levels of all main rivers were 1.5 to 3 times higher than the permitted level. MARD forecast that in the future further industrialisation and modernisation of Vietnam would cause greater pollution of rivers, where livelihoods based on aquaculture are carried out. Generally, the sensitivity of intensive shrimp farming to climate change was twice as much as that of extensive shrimp farming, with semi-intensive shrimp farming ranked at medium sensitivity (Fig. 3.6).

However, the adaptive capacity of natural capital was the highest for semi-intensive farming (0.581), intermediate for intensive farming (0.559), and the lowest for extensive farming (Fig. 3.6). This dimension was measured by changing the model of shrimp farming (NA1), changing cropping time (NA2), and having reserve ponds (NA3). Supporting the results for this index, the percentage of households changing cropping time was considerably high in both the intensive and semi-intensive systems (both 87%), whereas in the extensive system it was difficult to change cropping time (7%) due to its characteristic production method. Some reasons for changing shrimp cropping time were heavy rain reducing the level of water salinity (the optimal salinity range is 15‰–25‰ for shrimp farming [MOFI, 2016; Anh et al., 2010]) and drought causing severe evaporation and increasing the risk of disease; in such situations, farmers postpone the new crop until conditions are more suitable.

Moreover, the flexibility of changing the method of shrimp farming was different between the different cultivation systems. It is impossible to change the intensive system to the extensive model due to the small area and closed design of ponds which are not suitable for the latter. The intensive system can only change to semi-intensive by decreasing the density of stocking. In the case of heavily polluted water or a shortage of water due to drought, intensive shrimp farmers can decide to change to semi-intensive forms to adapt to adverse climate events. In contrast, under favourable climate conditions, semi-intensive farmers can change to intensive farming to improve profits due to the higher density of stocking. Extensive shrimp farmers would find it difficult to change to other forms because they require significant investment in facilities and equipment. Therefore, 15% of intensive shrimp farmers, 32% of semi-intensive farmers, and only 7% of extensive farmers would change the model of shrimp cultivation (Appendix 3.B). As described by farmers, reserve ponds help them to cope with water shortages in the dry season and avoid diseases transmitted from river water by treating it before using in shrimp ponds. The results for this indicator showed that 65% of intensive shrimp farming households have reserve ponds compared to 54.8% of semi-intensive shrimp farming households. In contrast, due to the method used in extensive shrimp farming, which lets river water in and out of ponds frequently, this system does not need reserve ponds.

The highest exposure and sensitivity to climate change of natural capital was shown by the intensive production system while its adaptive capacity was half the potential impact, leading to the highest LVI-IPCC for natural capital in this system (0.575). The semi-intensive farming system showed an intermediate level of vulnerability (0.531), whereas the vulnerability of the extensive shrimp farming system to climate change was relatively low (0.411; Fig. 3.6). The adverse impact of climate change on shrimp farming is obvious and will be more serious in the future, which is not only demonstrated by contemporary scientific evidence but also perceived by the farmers themselves (Table 3.6).

**Table 3.6. Shrimp farmers' perception of related climate events in the past and the future.**

| What extent of these events compared to past 10 years. | | | | | | |
|---|---|---|---|---|---|---|
| Droughts occur more often. | Droughts are shorter than they used to be. | Storms occur more frequently | Heavy rains occur more often. | Floods are less severe. | Sea level is higher than it was 10 years ago. | Coastal land is lost to the sea. |
| 4.423 | 1.637 | 2.243 | 4.134 | 3.590 | 4.103 | 3.983 |
| What extent of these events will be in the next 10 years. | | | | | | |
| In the future, droughts | In the future, droughts will become | In the future, storms | In the future, heavy | In the future, floods | In the future, sea | In the future, more |

| | | | | | | |
|---|---|---|---|---|---|---|
| will occur more often | shorter than they used to be. | will occur more frequently | rains will occur more often. | will be less severe. | level will be higher. | coastal land will be lost to the sea. |
| 4.693 | 2.157 | 2.600 | 4.457 | 2.747 | 4.390 | 4.537 |

*Note: The responses were rated using a Likert scale from 1 to 5, where 1 means 'definitely has not/will not' and 5 means 'definitely has/will'.*

**3.3.3 Physical capital**

Based on the Sustainable Livelihood Framework, physical capital in this study comprises internal and external property of the household that could be vulnerable to climate change. Internal property is the house and shrimp ponds and external property is freshwater, electricity supply, and roads. No intensive and semi-intensive shrimp farming household reported damage to the house due to climate (PE1) because the majority occupied cement and brick houses (PA1). While 53.5% of the extensive shrimp farmers lived in cottages or bungalows, 9% suffered damage due to climate (Appendix 3.B). The second indicator also showed less exposure to climate change, with rain and floods affecting 16% of the extensive shrimp ponds, but only 3.6% and 4.8% of the intensive and semi-intensive shrimp ponds (PE2). Extensive shrimp ponds are normally constructed with narrow, low dikes. Extensive shrimp farms located near coastal areas are frequently affected by tidal waves and sea level rise, and are easily flooded in the rainy season. In contrast, intensive and semi-intensive ponds are built carefully and firmly, and they are located far from coastal areas. Therefore, the exposure of extensive shrimp farms was higher than that of the other systems, but not considerably.

In the case of the sensitivity dimension, the shrimp farmers were satisfied with the electricity supply (PS1) provided through the sustainable shrimp farming strategy of the government. In contrast, none of the households had access to piped water (PS2), which contributes to health problems. This indicator has a positive relationship with the household's sensitivity to climate change. All households reported that rainwater and groundwater were used for cooking and sanitation, whereas groundwater was regarded as the main supply of freshwater, which could be vulnerable due to flooding or sea level rise. Furthermore, living far from the road, transport was considered to be susceptible to climate change. Approximately 80%

of the extensive farmers found it difficult to access the main roads due to their distance from farms (PS3), while only 42% of semi-intensive and 23% of intensive shrimp farmers were in that situation. As a result, extensive households were more sensitive to climate change in relation to physical capital than the others (Fig. 3.7)

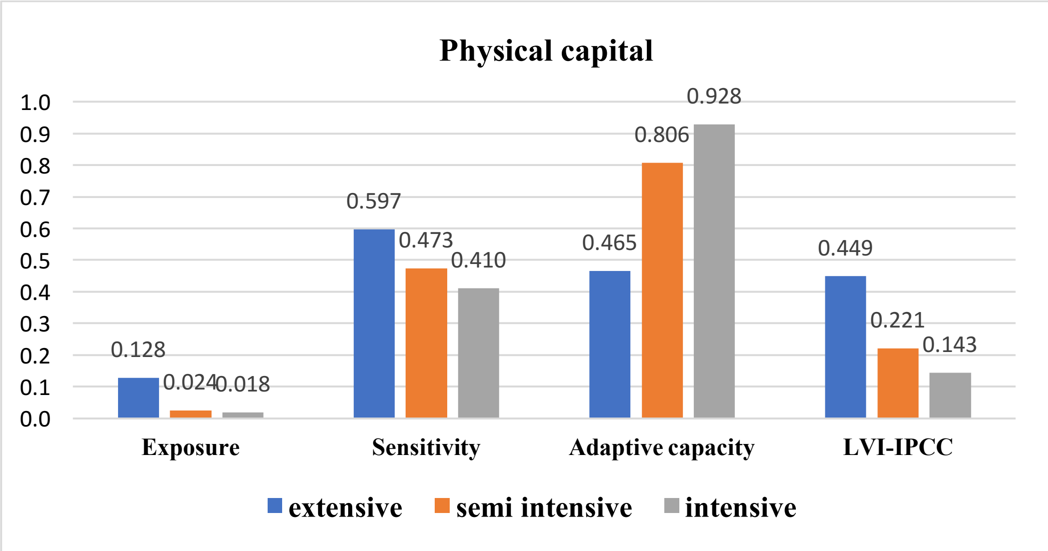



**Figure 3.7. Exposure, sensitivity, and adaptive capacity of physical capital in different shrimp farming systems.**

The adaptive capacity index was augmented by the percentage of households with cement and brick houses (PA). A high-quality house would help the household to feel secure and cope with extreme climatic events. In the Mekong Delta, a house built of cement and brick is regarded as safe in storms. While 80–90% of semi-intensive and intensive families lived in cement-brick houses, only 46.5% of the extensive families did. Therefore, the adaptive capacity of both intensive and semi-intensive shrimp farmers was more than double that of extensive farmers (Fig. 3.7).

The survey data showed that the LVI-IPCC of extensive shrimp farming was the highest compared to intensive and semi-intensive systems (Fig. 3.7) due to the extensive system having higher sensitivity and lower adaptive capacity, while intensive and semi-intensive systems showed the opposite trends for all components.

### 3.3.4 Social capital

According to DFID (1999), social capital concerns the relationships, networks, and access to information that people in the community use to pursue their livelihood strategies. Under a sustainable livelihood strategy, it is difficult to determine the level of social capital in a short time; it must be observed and assessed over an extended period (DFID, 1999). However, when measuring vulnerability to climate change, it is reasonable to evaluate the vulnerability index through related indicators such as access to information, means of communication, frequency of visiting relatives, entertainment, relationships with neighbours, and sharing experience of shrimp farming (Appendix 3.A).

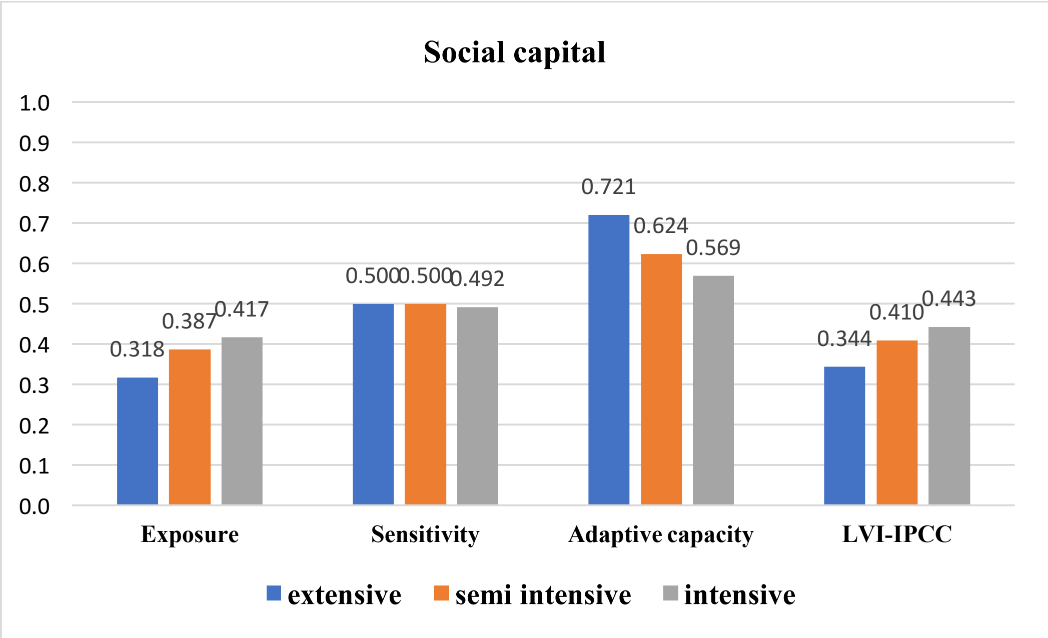



**Figure 3.8. Exposure, sensitivity, and adaptive capacity of social capital in different shrimp farming systems.**

The social capital could be affected by climate change in relation to accessing information daily, frequency of visiting relatives, and participating in local community activities. For instance, storms and heavy rain could cause electrical power outages leading to interruption of access to news via electronic media. Due to adverse climate patterns, farmers tend to pay more attention to their shrimp ponds; therefore, time would not be free to visit relatives or participate in community activities. The extensive shrimp farmers' exposure index was slightly lower than those of semi-intensive and intensive shrimp farmers (Fig.3.8) because farmers involved in extensive shrimp cultivation have more free time to visit their relatives

(SE2) and take part in local community activities (SE3) more frequently than the farmers engaged in semi-intensive or intensive shrimp farming (Appendix 3.B). However, farmers in all three models of farming had a similar sensitivity index because they all own mobile phones for communication in any case (SS2) and almost all families rely on television to entertain them every day (SS1). Therefore, values for the sensitivity dimension were the same for the three systems of shrimp farming.

In terms of the capacity to adapt to climate change, extensive shrimp farming was more favourable compared to the other systems. Due to living near to relatives (SA3), extensive shrimp farmers might benefit in case of hardship. All farmers in the study had a good relationship with their neighbours (SA1) and were ready to share their experiences (SA2) with others, which are considered social norms among rural people in Vietnam.

With a sensitivity index similar to that of the other two systems and lower exposure and higher adaptive capacity, households involved in extensive shrimp farming were less vulnerable to climate change in their social capital compared to shrimp farmers in the semi-intensive and intensive systems (Fig. 3.8).

### 3.3.5 Financial capital

Financial capital indicates all types of material property whose cash value can be estimated. It includes financial resources that can be accessed, invested, and consumed to achieve livelihood objectives (DFID, 1999). In shrimp farming, financial resources play a very important role in deciding whether to continue farming or whether to give up in case of suffering crop losses or needing to invest in more facilities and equipment to adapt to severe changes in climate.

The percentage of households that did not have access to bank loans was similar for extensive and intensive shrimp farming systems. Between 37.5% to more than 40% of the households were refused bank loans (FE1). The main reasons for this problem were the banks' fear of the high risk in intensive shrimp farming and the low mortgage value of the properties of extensive shrimp farmers. In contrast, the semi-intensive shrimp farmers had more opportunities to obtain bank loans (only 23.6% of the households were refused bank loans) because this system is perceived as lower risk as demonstrated by only 16% of the households losing the recent shrimp crop (FE3) and the failure of only 19.4% of the households to pay their loans

(FE2), compared to 40% and 52% for the same indicators for intensive farming. Although very few extensive farming households had lost the last shrimp crop (2.3%), 66.7% failed to pay back their bank loans. As a result, semi-intensive farming had the lowest exposure to climate change in terms of financial capital, while the highest exposure was shown by the intensive farming system (Fig. 3.9).

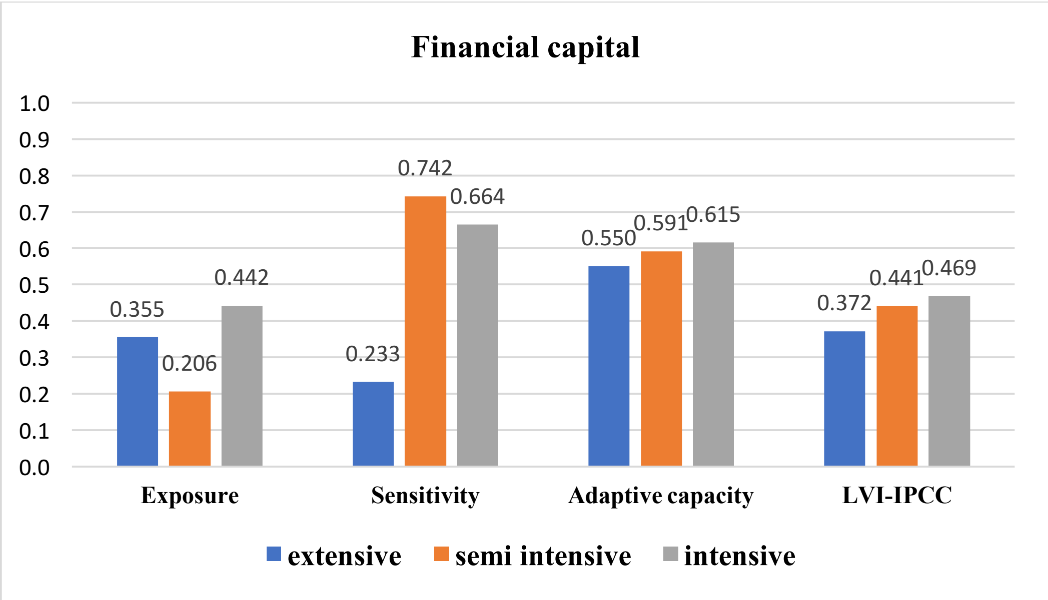



**Figure 3.9. Exposure, sensitivity, and adaptive capacity of financial capital in different shrimp farming systems**

The sensitivity dimension of financial capital was higher for both intensive and semi-intensive farming systems (Fig. 3.9), which was due to the large proportion of households having bank loans (FS1) and depending on shrimp farming as the only source of income (FS2) which would make these households vulnerable if they experience consecutive losses of crops. By contrast, extensive farming had a variety of sources of income, making its sensitivity index the lowest.

Most of the farmers owned the land under shrimp cultivation (FA1), which contributed to the increase in their adaptive capacity. In addition, a considerable number of shrimp farmers had savings accounts (FA2), especially intensive (74.9%) and semi-intensive farmers (72.6%) compared to extensive farmers (48.8%). However, 18.6% of the extensive shrimp farmers could borrow money from their relatives (FA3), a slightly higher proportion than that for semi-intensive and intensive shrimp farmers. Although loans from relatives also have to be paid back, they are less burdensome than bank loans because they do not tend to carry an interest rate and are not based on mortgaged properties, but on the relationship and prestige. In general, the adaptive capacity index of the three shrimp farming methods was relatively high, and were 0.550, 0.591, and 0.615 for extensive, semi-intensive, and intensive farming, respectively (Fig.3.9). Finally, based on the three dimensions, intensive shrimp farming was the most vulnerable to climate change in relation to financial capital and the least vulnerable was extensive shrimp farming (Fig. 3.9).

**3.3.6 Overall indices**

Overall, the shrimp farmers of the three farming systems were significantly sensitive to climate change in all livelihood assets. The intensive and semi-intensive shrimp farming systems were exposed strongly to climate change in their natural capital, while human and physical capital had a very low exposure index. Therefore, the potential impact which is combined between exposure and sensitivity dimensions was relatively high in general. Although the potential impacts were higher on intensive and semi-intensive farming systems than on the extensive farming system for three out of the five types of livelihood capital, the adaptive ability of intensive and semi-intensive systems was higher for almost all types livelihood capital compared to that of the extensive farming system (Fig. 3.10). As a result, the overall LVI-IPCC of extensive farmers was the highest (0.435) and that of the intensive farmers was intermediate (0.4), while that of the semi-intensive farmers was the lowest (0.385), indicating that they are the least vulnerable to climate change.

This study's findings are similar to the results of An et al. (2016) that intensive shrimp farming was less vulnerable to climate change than extensive farming because the intensive shrimp farmers have higher adaptive capacity than other farmers. By contrast, Kam et al. (2012) and Ha et al. (2013) concluded that intensive shrimp farming was more vulnerable to climate change than other forms because intensive farmers faced frequent crop losses due to poor water quality management and unstable shrimp prices (Ha et al., 2013). Kam et al. (2012) argued that lower operational costs and autonomous adaptation costs resulted in extensive shrimp farming being less vulnerable than semi-intensive and intensive farming systems. These differences in results may be due to different approaches, methods of vulnerability assessment, and study locations.

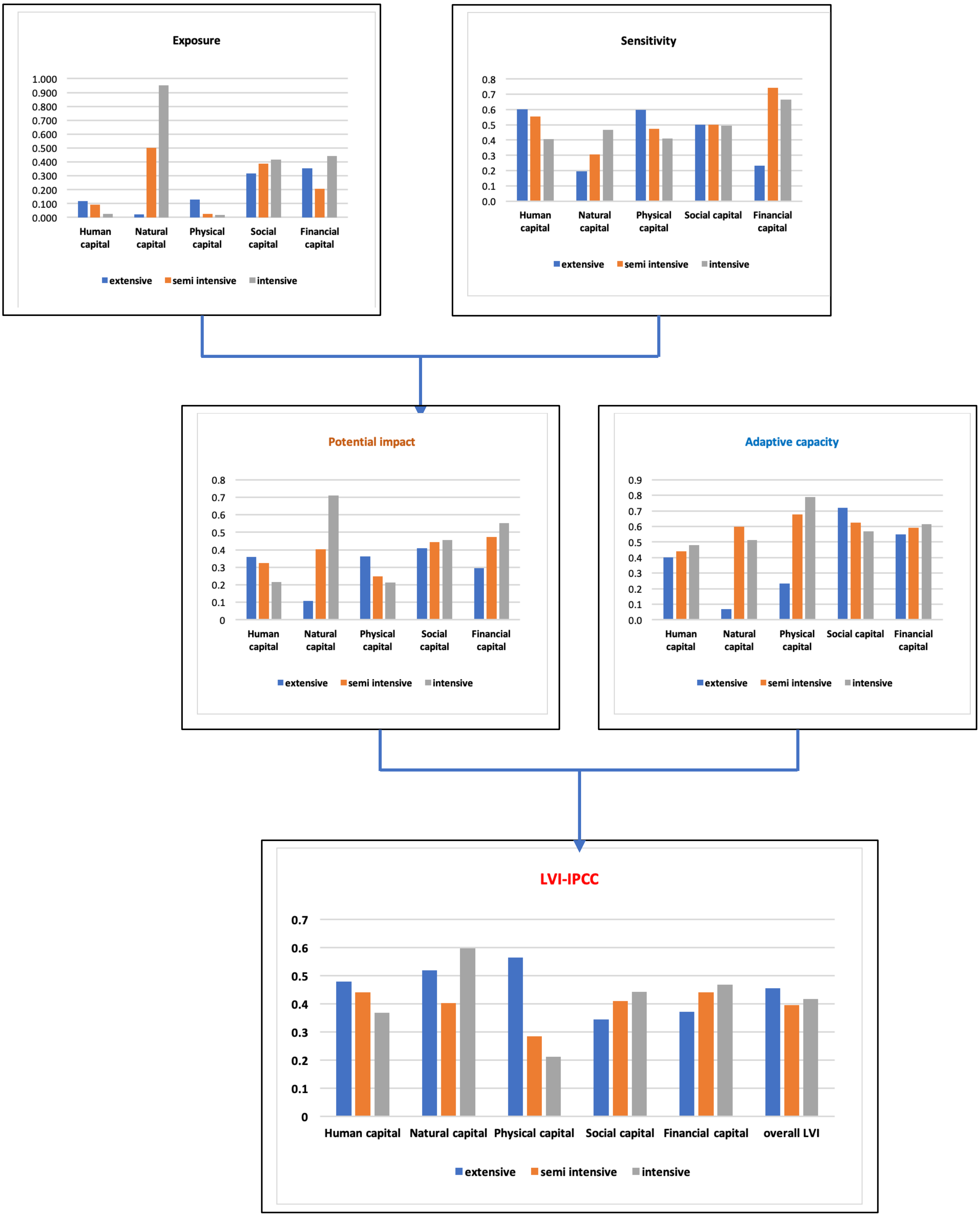



**Figure 3.10. Summary of the vulnerability assessment process.**

### 3.4 Conclusions and recommendations

This study assessed the LVI of shrimp farming households under the IPCC framework (LVI-IPCC) using several indicators based on five livelihood assets in the context of climate change. It found that the livelihood of extensive shrimp farming households was the most vulnerable to climate change. Households engaged in semi-intensive shrimp farming had the lowest level of vulnerability.

In relation to human capital and physical capital, extensive shrimp farmers were the most vulnerable to climate change (Fig.3.10) because their farms are located in coastal areas and they live far from hospitals (HS1), schools (HS3), and main roads (PS3). Therefore, extensive shrimp farmers could suffer from poor health (HE2) and illnesses (HE3), and their children stop schooling early (HS2). In addition, their ponds are damaged due to sea level rise and tidal waves (PE2).

Intensive shrimp farmers were the most vulnerable to climate change in terms of natural, financial, and social capital (Fig.3.10). The emerging problems include disease outbreaks in shrimp (NE1) and the use of groundwater for farming (NE2) due to irregular climate patterns such as drought and fluctuating temperature between night and day. In addition, polluted water resources (NS1) would exacerbate sensitivity to climate change in the future. The hazards of climate change caused farmers to have no free time to visit their relatives (SE2) or join community activities (NE3). Furthermore, intensive shrimp farmers found it difficult to access credit from banks (FE1) and relatives (FE2) due to frequent crop losses (FE3). The semi-intensive shrimp farmers had an intermediate level of vulnerability for all assets except for natural capital in which case their vulnerability was the lowest.

This study is limited due to the shortage of data for natural disasters caused by climate change that have affected shrimp farmers' livelihood. All 42 indicators were selected based on many publications and expert knowledge, which may have introduced bias, although the indicators are suitable for the shrimp farming systems in the Mekong Delta in general and Tra Vinh province in particular. However, the results of this study may contribute to the understanding of the vulnerability of shrimp farmers in Tra Vinh to climate change, and may provide a useful and specific picture of the LVI of each shrimp farming system, which would help policymakers to support farmers with appropriate solutions based on plans for economic development of the Province.

**Recommendations**

The following solutions are recommended to decrease the vulnerability to climate change of shrimp farmers' livelihoods in each farming system. Shrimp farmers in the extensive systems should build dikes to prevent inundation due to sea level rise and high tides. Farmers should be encouraged to plant mangrove as a buffer against tidal waves and to absorb pollutants from aquaculture activity because the particular characteristic of extensive shrimp cultivation require frequent exchanges of water without reserve ponds. The government should consider building more roads, hospitals, and schools and improving the existing infrastructure in extensive shrimp farming areas.

In the case of intensive and semi-intensive shrimp production, firstly, local officials should appeal to shrimp farmers to stop extracting groundwater and propagandise the consequences of subsidence due to excessive use of groundwater. Secondly, strict penalties should be instituted for discharging untreated water from shrimp ponds to prevent the risk of disseminating diseases and to protect the ecosystem. Finally, reservation ponds should be made a requirement for intensive and semi-intensive shrimp farming systems to ensure that the quality of water resources is managed and disease outbreaks are limited.

In general, the government should invest in piped water to ensure all shrimp farmers can access freshwater for domestic purposes to decrease their sensitivity to climate change in terms of physical capital. The government should offer preferential interest rates on loans for shrimp farmers who have experienced crop losses. This would enable shrimp farmers to reinvest in a new crop or equipment and materials to improve their ability to adapt to climate change.

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**Appendix 3.A: Indicators of vulnerability to climate change basing on five forms of livelihood capital.**

| **Livelihood assets** | **Dimension of vulnerability** | **Indicators** | **Explanation of indicators** | **Survey question** | **Source of indicators** |
|---|---|---|---|---|---|
| Human capital | Exposure | Percentage of households with insufficient food (HE1) | I use two questions to decide whether a household is sufficient food or not.<br>If a household has at least three meals per day and each meal with at least three kinds of food, this household is sufficient food. Otherwise, this household is insufficient food. | 1. How many meals does your family has per day?<br>2. What kind of food does your family have each meal usually? | R. Pandey et al., 2017; Urothody et al., 2010; R. R. Pandey et al., 2012; Hahn et al., 2009 |
| | | Percentage of households with poor health (HE2) | The indicator lets us know the status quo of households' health, which affects the livelihood more or less indirectly.<br>If a household health value is more than 3, it is good health. Otherwise, it is lower than or equal to 3, it is poor health. | In your opinion, what extent you agree with the following status quo of your family health.<br>On scale from 1 to 5, where one | Urothody et al., 2010; R. Pandey et al., 2012; Hahn et al., 2009; X. Hua et al., 2017; H.Chen et al., 2013 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | means "definitely poor health" and five means "definitely good health". | Allison et al., 2009 |
| | | Percentage of households with children leaving school or not afford to school (HE3) | If a household with children leaving school or not afford to school, it is assigned value = 1, otherwise value =0.<br>Children's education plays an important role in assessing households' livelihood is good or not. Furthermore, the education factor decides farmers still staying current livelihood or migrating another place for better of their children's education with the hope of a bright future. (UN 2006; UNDP 2003) | Are your children going to school? | C. Donohue, E. Biggs. 2015; |
| | Sensitivity | Percentage of households with disease due to climate factors (HS1) | This indicator measures the feasible vulnerability of livelihood related to households' health. If the households reported that their families were usually ill by climate change, their vulnerability to climate change is apparently. | What are the main causes of your family members disease? | Rajiv Pandey et al., 2017. Rajiv Pandey et al., 2012. |

| | | | | | |
|---|---|---|---|---|---|
| | | Percentage of households far from hospital (HS2) | If the households live far away from a hospital, they might find it difficult to get there in an emergency or abrupt case of illness. So, I considered it as a sensitive factor of climate vulnerability.<br>Because there is no definition of how far it is. In other words, we do not have a standard of distance that calls 'far'. Therefore, according to data collected through the survey, I defined the meaning by 'far' by comparing the original distance with the average distance of the whole sample. As a result, a household would be considered as 'far' if its distance value is longer than the average distance, and otherwise would be 'not far'. | How far is it from your house to the nearest hospital or medicine center? | Experts' opinions. |
| | | Percentage of households far from school. (HS3) | Having the same explanation of HS2, I also compared households' distance to their children's school with the average distance of the whole sample. A household is concluded 'far' as its distance is over the average value, and otherwise is considered 'not far'.<br>I did not concern their children studying college or university as its really very far and usually the children do not go to their home every day. Moreover, there is only one college/ university in | How far is it from your house to your children's school? | Experts' opinions. |

| | | | | | |
|---|---|---|---|---|---|
| | | | Tra Vinh province located in the center city of Tra Vinh province. Thus, the undergraduate students from high school may enter the college/university in Tra Vinh province or other provinces that are farther from home.<br>Indirectly, this factor affects farmers' livelihood. As it takes time and cost of parent for driving or pick up children. In the case of children going to school themselves, it also takes their parent's concerns and costs. | | |
| | | Ratio of non-labor per total member of household (HS4) | This indicator shows the dependency ratio which becomes a burden to the family. If this ratio is high, it would be a positive relationship with the number of dependent members in the household. Non-labor includes children who are too young to work, old members are too old to work and disabled members. | Please let us information about your family member labor and education degree. (this question is used for many related purpose, it contains a lot of information) | R. Pandey et al., 2017; Urothody et al., 2010; R. R. Pandey et al., 2012; Hahn et al., 2009 |

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|---|---|---|---|---|---|
| | Adaptive capacity | Household labor capacity (HA1) | If this indicator is high, the human capital would be strengthened and greater adaptive capacity to climate change.<br>The value of household labor capacity is calculated as follows:<br>A Non-labor =0 (including children too young to works, elder members too old to work, and disabled members cannot work)<br>A Semi-labor = 0.5 (including children and elder members who can do simple jobs in house or farming)<br>A Full- labor =1.0 (who are main members can do full time in farming activity)<br>The values of the labor capacity of all family members are summed up. Afterward, it is normalized by the equation (1) | Please let us information about your family member labor and education degree. (this question is used for many related purpose, it contained a lot of information) | X. Hua et al., 2017 |
| | | Household education level (HA2) | The Education of each household was calculated by averaging the summing up all members' education of the family. Specifically, each level education of member was assigned a value such as: primary school = 6; secondary school =9; | Please let us information about your family member labor and education degree. | X. Hua et al., 2017; Huynh et al., 2018; Scoones 1998. |

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| | | | high school =12; college or university =16, non-education or illiterate = 0. The values of the education level of all family members are summed up. Afterward, I normalized it by the equation (1) | (this question is used for many related purpose, it contained a lot of information) | |
| | | Number of experience years (HA3) | It assumed that the head of household with longer time shrimp farming would be more relative advantage of the adaptive capacity of coping with climate change. | How many years do you experience shrimp farming? | Experts' opinions. |
| | | Percentage of households with taking part in training course of shrimp farming. (HA4) | Participating in the training courses brings a lot of benefits to farmers such as updated knowledge of shrimp cultivating, environmental responsibility in farming, controlling, and treating diseases. All of those increase the ability of adaptation to climate change for shrimp farmers. | Have you taken any shrimp training course? | Experts' opinions. |
| | | Percentage of households cultivate live stocks and vegetables (self- | This indicator shows the ability of a household can supply a certain food for daily meals. It is assumed that household can cultivate livestock and vegetables for themselves, they are more qualified in food security. | Do you cultivate some kinds of livestock and vegetable for food? | Experts' opinions. |

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|---|---|---|---|---|---|
| | | supply food) (HA5) | | | |
| Natural capital | Exposure | Percentage of households reporting some diseases with shrimp due to climate in three recent years. (NE1) | The key risk of shrimp farming is the disease outbreaks. They took a lot of cost for caring and treating, even lost at all.<br>I used two questions to find out which household reported shrimp disease due to climate factors. | 1. Have you found any disease with you shrimp for three years recently?<br>2. What were the main causes of these disease or epidemic of shrimp in the last three years? | R. Pandey et al., 2017; |
| | | Percentage of households extracting ground water for shrimp farming (NE2) | Using groundwater has never been encouraged because it was named as one of the causes of land subsidence. In this case, if households were using groundwater to add to shrimp ponds, they did not realize the responsibility of preserving the common pool. It also proved that they were vulnerable to climate change, such as long-time dry caused water level in ponds decreasing. | Do you pump groundwater into your shrimp ponds? | Experts' opinions. |

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|---|---|---|---|---|---|
| | Sensitivity | Percentage of households reporting river water was polluted increasingly (NS1) | The quality of water resources affects directly shrimp farming. Although assessment of the quality of river water would be reliable and exactly with a technical test, just the result of this reflects merely at one point in time and at one of the places. The shrimp farmers who utilize this water directly and regularly, so they are able to realize how the quality of water is.<br>I decided to use this indicator for the sensitivity dimension of Natural capital., If a household said the water they are using in shrimp farming in polluted conditions, they are risk at farming.<br>Because the indicator was calculated by a Likert scale with five points, I assigned 'polluted' for a value from 3 to 5 and 'not polluted' for values are 1 and 2. | What is water resource for shrimp farming like currently?<br><br>On scale from 1 to 5, where one means "definitely not polluted" and five means "very high polluted". | R. Pandey et al., 2012; |
| | | Percentage of households reporting strange diseases in shrimp farming (NS2) | Strange diseases were considered as a result of climate change indirectly. It is assumed as a vulnerability factor to shrimp farmer's livelihood. | Have you found any stranger disease with your shrimp recently? | Experts' opinions. |

| | | | | | |
|---|---|---|---|---|---|
| | | Percentage of household's pond far from river (water resource) (NS3) | If the ponds are far away from the river, households might find it difficult to get or discharge water and bear more cost to do that. So, I considered it as a sensitive factor of climate vulnerability.<br>Because there is no definition of how far it is. In other words, we do not have a standard of distance that calls 'far'. Therefore, according to data collected through the survey, I defined the meaning of 'far' by comparing the original distance with the average distance of the whole sample. As a result, a pond would be considered as 'far' if its distance value is longer than the average distance, and otherwise would be 'not far'. | How far is it from your shrimp ponds to water resource? | C. Donohue, E. Biggs. 2015; |
| | Adaptive capacity | Percentage of households changing model of shrimp farming (NA1) | Changing shrimp model farming is considered a way to adapt to current environmental conditions and satisfy expected earnings. Base on households' financial status and experience they decided or did not. So, the indicator has a positive relationship with adaptive capacity. | Have you ever change shrimp farming model? (*from extensive to semi-intensive/ intensive; semi-intensive to intensive or vice versa)* | R. Pandey et al., 2017;<br>R. Pandey et al., 2012 |

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|---|---|---|---|---|---|
| | | Percentage of households changing shrimp farming time. (NA2) | Climate change is one of the main causes that caused crop cycle time to change. Shrimp farming is inevitable, the behavior of change time of crop to avoid extreme climate or adverse climate. | Have you ever changed shrimp farming time in a year? | R. Pandey et al., 2017; |
| | | Percentage of households having reservation ponds. (NA3) | It is assumed that the reservation pond helps shrimp farmers treating water before shrimp cultivating, the way avoids the risk of casual agents from original river water. And treating discharged water from shrimp ponds as a conceptual environment which protects their livelihood activity in the future. | Do you have ponds for treating water-waste before discharging it into rivers? | Experts' opinions. |
| Physical capital | Exposure | Percentage of households with house damaged due to climate (PE1) | The indicator reveals the consequence of extreme climate events happened in recent years. | Has your house ever been damaged due to climate? | R. Pandey et al., 2017; |
| | | Percentage of households with shrimp ponds damaged due to climate (PE2) | Shrimp ponds certainly are the main asset and play an important role in shrimp farming, so their exposure to climate would be considered. | Have your shrimp ponds ever been damaged due to climate? | Experts' opinions. |

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|---|---|---|---|---|---|
| | Sensitivity | Percentage of household having no access to electricity (PS1) | It would be sensitive if a household has no access to electricity. Because shrimp farming in any model always needs power to its activities. | Do you have access to electricity resources?<br>□ Yes, government electricity line reaches my farm.<br>□ Yes, but I have to invest in private electricity line for access.<br>□ No, I have no access. | C. Donohue, E. Biggs, 2015; |
| | | Percentage of household having no access to pipe water (PS2) | Have no access to piped water contributes to a predicament of health issues. This indicator has a positive relationship with the household's sensitivity to climate change context. | What fresh water do your family use?<br>□ well *(groundwater)*<br><br>□ river water | R. Pandey et al., 2017; Urothody et al., 2010; R. R. Pandey et al., 2012; Hahn et al., 2009 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | □ piped water *(water from government supply)*<br>□ rain water *(households store rain water by big vases)* | |
| | | Percentage of household far from road (PS3) | This indicator should be included in the sensitivity dimension because the comfortable transport degree would improve household livelihood, they are easy to approach every means of their life and their farming activities. And as mentioned in HS2, NS3 the same for the explanation of value measure. | How far is it from your house to the nearest road? | Experts' opinions. |
| | Adaptive capacity | Percentage of households with cement and brick house (PA) | As mentioned in PE1, the firm quality of the house would help household feel safe and cope with extreme climatic events. In the case of the Mekong Delta, a house is built of cement and brick considered as a safe house with storms. | What kind of your house?<br>1=cottage/ bungalow<br>2= cement level 4 (life span up to 30 years) | X. Hua et al., 2017; Huynh et al., 2018; R. Pandey et al., 2017; |

| | | | | | |
|---|---|---|---|---|---|
| | | | | 3= cement level 3 (life span up to 40 years)<br>4=cement level 2 (life span up to 70 years)<br>5=cement level 1(life span up to 80 years) | |
| Social capital | Exposure | Percentage of households with no access to media information (SE1) | Getting information daily plays an important role in shrimp farming such as weather, season crop incentive, fluctuation of shrimp price, and so on. Without this information, easy to make mistakes in the decision or not right-time decisions. | How do you get daily information? | R. Pandey et al., 2017; |
| | | Percentage of households with no visiting relatives for over 3 months (SE2) | In the spiritual aspect, people are impossible living without relatives. Because the relationship encourages us to each other in life. A good and closed relative when we meet each other regularly. We should balance work and metal needs. As intangible assets of our lives are lost or less, it means that we are vulnerable visibly. | How long have not you visited your relatives?<br> one – three months<br> three- six months | Experts' opinions. |

| | | | | | |
|---|---|---|---|---|---|
| | | | | □ more six months<br>□ never | |
| | | Percentage of households with no taking part in local community activity. (SE3) | Social activities are important to our life, especially in rural communities. Attending to local community activity generate linking between farmers, enhance experience sharing chance. The advantage of a social resources is to improve livelihoods, which is usually in the form of social networks or connections (DFID, 1999). | How long have not you taken part in community activity? | Experts' opinions. |
| | Sensitivity | Percentage of households relying on television for entertainment (SS1) | A variety of means of entertainment is required for better livelihood. It also reflects the level of living standard of household or level of wealth. | Usually, what mean does your family entertainment every day? | C. Donohue, E. Biggs. 2015; |
| | | Percentage of households having no cell phone for communication. (SS2) | Communication exchange is basically required to enhance social relationships and other benefits in life and work (S. Cecchini & Scott, 2003). | Please let us know what assets do you have? By choosing from the list below. | C. Donohue, E. Biggs. 2015; |

| | | | | | |
|---|---|---|---|---|---|
| | Adaptive capacity | Percentage of households having good relationship with neighbor. (SA1) | Relationships with neighbors would enhance the household's adaptive capacity to climate change or extreme climate events. A good relation you would benefit from the neighbor's willingness to help or support. Although you did not get any material supports, you felt warm your heart when you realize that someone else advocated or stood behind you.<br>This indicator was evaluated by three questions. I assigned a value to a household's good relationship with neighbor was 1 if 'yes' answers have been recorded in question 1&2 and '3' answer for question 3 which was measured by a Likert scale of five points. | 1. Are your neighbors ready to help you in some normal cases?<br>2. Are your neighbors ready to share experience with you?<br>3. Please indicate what extent do you feel your neighbors' relationship?<br>On scale from 1 to 5, where one means "definitely bad" and five means "definitely good". | R. Pandey et al., 2017; |

| | | | | | |
|---|---|---|---|---|---|
| | | Percentage of households sharing experience to others (SA2) | One of qualified characteristic of human is sharing. In Vietnam, there is a notable sentence is that 'happiness is simply sharing not getting'. Altruistic behavior or attitude is always appreciated in any case, it also enhances the relationship with each other. Especially, in shrimp farming, sharing experience you have had, you would get a good relationship and respect. You have ever shared experience of shrimp farming that means your adaptive capacity is strong. | Who have you ever shared your experience with?<br>□ relatives<br>□ neighbors<br>□ none, because I think they have known already. | R. Pandey et al., 2017; |
| | | Percentage of households living near their relatives (less than 10km) (SA3) | According to the current situation of households, culture, and society, and including opinions from experts, a radius of 10 km around the household was considered as an advantage in case of emergent needing a support or helps from relatives.<br>Comparing actual distance from the household to the nearest relatives with the standard distance of 10 km to decide a household is 'near' or 'far'. | How far is it from your house to the nearest relatives? | Experts' opinions. |

| | | | | | |
|---|---|---|---|---|---|
| Financial capital | Exposure | Percentage of households have been rejected loan by banks (FE1) | This indicator shows vulnerability clearly. It is assumed that a household would find it difficult to reinvest to farming after a lost crop or during time shrimp cultivating. | Have you ever been rejected bank loan? | Experts' opinions. |
| | | Percentage of households cannot afford to pay the loan in due. (FE2) | It discloses the financial situation that a household was faced with. There are a lot of causes leading to this consequence including climatic cause. If households fail to pay the loan, their chance to get credit in the future is nearly zero. So, I considered this indicator as an exposure dimension of financial capital. | If you have ever borrowed money for shrimp farming. How was your paying for the last loan? | Experts' opinions. |
| | | Percentage of households with loss of the last shrimp crops. (FE3) | If the last crop is lost, shrimp farmers' budget would be affected. They would confront a variety of difficulties in continuing farming. | What is the last shrimp crop like? ☐ profit ☐ loss ☐ breakeven | R. Pandey et al., 2017; |
| | Sensitivity | Percentage of households with bank loans (FS1) | If you are owed money from a bank, you have a burden to repay it. Success in shrimp farming in the climate change context is never an easy story. It requires a lot of techniques, efforts and a bit of | Have you been borrowing money for shrimp farming? From who? | X. Hua et al., 2017; |

| | | | | | |
|---|---|---|---|---|---|
| | | | a hazard/lucky. So, the farmers bear a bank loan, they also bear financial risk. | □ From relatives<br>□ Friends<br>□ From banks<br>□ Do not borrow | |
| | | Percentage of households depending on shrimp farming as an only source of income (FS2) | Solely income from shrimp farming would be difficult to manage over predicament situation. So, this indicator includes the sensitivity dimension of financial capital. | Do you have any other income beside income from shrimp farming? | R. Pandey et al., 2017;<br>R. Pandey et al., 2012;<br>Urothody et al., 2010 |
| | Adaptive capacity | Percentage of households owning land (FA1) | It is assumed that a household owns the land has advantages in the financial aspect. Farmers could use land as a pledging or mortgage for credits if they need. | Do you own land or rent land for farming?<br>Own land: □<br>Rent land: □ | R. Pandey et al, 2017 |
| | | Percentage of households with a saving account. (FA2) | Having a saving account would be considered as a guarantee for bad financial situations. In the case of reinvesting shrimp farming or family member be illness or catastrophe. | Do you have a saving account?<br>□ Yes □ No | Experts' opinions. |

| | | | | | |
|---|---|---|---|---|---|
| | | Percentage of households could borrow money from relatives. (FA3) | This indicator relates to SE2 and SA3, if a household has a good relationship with relatives or lives near them, it would be a favorable dimension when financial problems occur. The relatives-credit would facilitate the household dealing with the bad financial situation, it is similar to the bank credits. | Have you been borrowing money for shrimp farming? From who?<br>□ From relatives<br>□ Friends<br>□ From banks<br>□ Do not borrow | X. Hua et al., 2017; Urothody et al., 2010 |

## Appendix 3.B. Value of Indicators for three dimensions of each capital and LVI-IPCC

| Household capital | Dimension of Vulnerability | Indicators | Indicator value ($S_{vi}$) | | | Dimension value ($M_{vi}$) | | | LVI-IPCC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Extensive (Ext.) | semi-intensive (Semi-int.) | Intensive (Int.) | **Ext.** | **semi-int.** | **Int.** | **Ext.** | **semi-int.** | **Int.** |
| **Human capital** | Exposure | HE1 | 0.000 | 0.000 | 0.000 | **0.116** | **0.091** | **0.027** | **0.480** | **0.441** | **0.368** |
| | | HE2 | 0.140 | 0.113 | 0.072 | | | | | | |
| | | HE3 | 0.209 | 0.161 | 0.010 | | | | | | |
| | Adaptive capacity | HA1 | 0.384 | 0.352 | 0.301 | **0.400** | **0.441** | **0.481** | | | |
| | | HA2 | 0.288 | 0.298 | 0.417 | | | | | | |
| | | HA3 | 0.373 | 0.348 | 0.359 | | | | | | |
| | | HA4 | 0.093 | 0.613 | 0.774 | | | | | | |
| | | HA5 | 0.860 | 0.597 | 0.554 | | | | | | |
| | Sensitivity | HS1 | 0.442 | 0.387 | 0.344 | **0.603** | **0.555** | **0.406** | | | |
| | | HS2 | 0.744 | 0.694 | 0.477 | | | | | | |
| | | HS3 | 0.651 | 0.565 | 0.179 | | | | | | |
| | | HS4 | 0.573 | 0.574 | 0.623 | | | | | | |
| **Natural capital** | Exposure | NE1 | 0.047 | 0.726 | 1.000 | **0.023** | **0.500** | **0.951** | **0.531** | **0.411** | **0.575** |
| | | NE2 | 0.000 | 0.274 | 0.903 | | | | | | |
| | Adaptive capacity | NA1 | 0.070 | 0.323 | 0.154 | **0.047** | **0.581** | **0.559** | | | |
| | | NA2 | 0.070 | 0.871 | 0.872 | | | | | | |
| | | NA3 | 0.000 | 0.548 | 0.651 | | | | | | |
| | Sensitivity | NS1 | 0.395 | 0.629 | 0.851 | **0.194** | **0.306** | **0.468** | | | |
| | | NS2 | 0.000 | 0.000 | 0.000 | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NS3 | 0.186 | 0.290 | 0.554 | | | | | | |
| **Physical capital** | Exposure | PE1 | 0.093 | 0.000 | 0.000 | **0.128** | **0.024** | **0.018** | **0.449** | **0.221** | **0.143** |
| | | PE2 | 0.163 | 0.048 | 0.036 | | | | | | |
| | Adaptive capacity | PA | 0.465 | 0.806 | 0.928 | **0.465** | **0.806** | **0.928** | | | |
| | Sensitivity | PS1 | 0.000 | 0.000 | 0.000 | **0.597** | **0.473** | **0.410** | | | |
| | | PS2 | 1.000 | 1.000 | 1.000 | | | | | | |
| | | PS3 | 0.791 | 0.419 | 0.231 | | | | | | |
| **Social capital** | Exposure | SE1 | 0.000 | 0.000 | 0.000 | **0.318** | **0.387** | **0.417** | **0.344** | **0.410** | **0.443** |
| | | SE2 | 0.186 | 0.258 | 0.292 | | | | | | |
| | | SE3 | 0.767 | 0.903 | 0.959 | | | | | | |
| | Adaptive capacity | SA1 | 0.698 | 0.645 | 0.764 | **0.721** | **0.624** | **0.569** | | | |
| | | SA2 | 0.930 | 0.903 | 0.913 | | | | | | |
| | | SA3 | 0.535 | 0.323 | 0.031 | | | | | | |
| | Sensitivity | SS1 | 1.000 | 1.000 | 0.985 | **0.500** | **0.500** | **0.492** | | | |
| | | SS2 | 0.000 | 0.000 | 0.000 | | | | | | |
| **Financial capital** | Exposure | FE1 | 0.375 | 0.263 | 0.400 | **0.355** | **0.206** | **0.442** | **0.372** | **0.441** | **0.469** |
| | | FE2 | 0.667 | 0.194 | 0.520 | | | | | | |
| | | FE3 | 0.023 | 0.161 | 0.405 | | | | | | |
| | Adaptive capacity | FA1 | 0.977 | 0.887 | 1.000 | **0.550** | **0.591** | **0.615** | | | |
| | | FA2 | 0.488 | 0.726 | 0.749 | | | | | | |
| | | FA3 | 0.186 | 0.161 | 0.097 | | | | | | |
| | Sensitivity | FS1 | 0.395 | 0.500 | 0.390 | **0.233** | **0.742** | **0.664** | | | |
| | | FS2 | 0.070 | 0.984 | 0.938 | | | | | | |
| **Overall LVI-IPCC** | | | | | | | | | **0.435** | **0.385** | **0.400** |

**Appendix 3.C. Statistic data of Shrimp farming from the Aquaculture Department of Tra Vinh province over last 6 years.**

*Number of shrimp households*

| Year | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| intensive | 14,842 | 13,831 | 15,928 | 20,134 | 25,829 | 25,805 |
| semi-intensive | 2,050 | 1,185 | 1,306 | 1,132 | 1,285 | 580 |
| extensive | 11,587 | 16,065 | 11,705 | 14,420 | 12,805 | 17,881 |
| **Total** | **28,479** | **31,081** | **28,939** | **35,686** | **39,919** | **44,266** |

*Area of shrimp farming (hectare)*

| Year | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| intensive | 6,651 | 6,998 | 7,726 | 9,035 | 4,412 | 10,367 |
| semi-intensive | 1,163 | 758 | 769 | 529 | 435 | 301 |
| extensive | 17,018 | 20,045 | 15,197 | 21,143 | 27,553 | 22,310 |
| **Total** | **24,832** | **27,801** | **23,692** | **30,707** | **32,400** | **32,978** |

*Output of shrimp farming (ton)*

| Year | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| intensive | 29,998 | 26,573 | 31,559 | 38,496 | 41,849 | 50,923 |
| semi-intensive | 1,512 | 1,137 | 984 | 529 | 566 | 392 |
| extensive | 5,523 | 7,216 | 5,319 | 4,017 | 4,408 | 4,016 |
| **Total** | **37,033** | **34,926** | **37,862** | **43,043** | **46,823** | **55,330** |

**Appendix 3.D Example of calculating the LVI-IPCC for the Human capital of the intensive shrimp farming.**

| Human capital | Average values | Max values | Min values | Normalized values | Dimension values |
|---|---|---|---|---|---|
| Percentage of households with insufficient food (HE1) | 0 | 100 | 0 | 0.000 | 0.027 |
| Percentage of households with poor health (HE2) | 7.2 | 100 | 0 | 0.072 | |
| Percentage of households with children leaving school or not afford to school (HE3) | 10 | 100 | 0 | 0.010 | |
| Percentage of households with disease due to climate factor (HS1) | 34.4 | 100 | 0 | 0.344 | 0.406 |
| Percentage of households far from hospital (HS2) | 47.7 | 100 | 0 | 0.477 | |
| Percentage of households far from school. (HS3) | 17.9 | 100 | 0 | 0.179 | |
| Ratio of non-labor per total member of household (HS4) | 0.44 | 0.71 | 0 | 0.623 | |
| Household labor capacity (HA1) | 1.903 | 4 | 1 | 0.301 | 0.481 |
| Household education level (HA2) | 9.904 | 18.5 | 3.75 | 0.417 | |
| Number of experience years (HA3) | 7.185 | 20 | 0 | 0.359 | |
| Percentage of households with taking part in training course of shrimp farming. (HA4) | 77.7 | 100 | 0 | 0.774 | |
| Percentage of households cultivate live stocks and vegetables (self- supply food) (HA5) | 55.4 | 100 | 0 | 0.554 | |

Aggregation steps, a weighted arithmetic mean was applied using equal weights.

**Step 1**. Calculating normalized value of each indicator (repeat for all indicators)

$I_{HA1}$ = (average – min. value)/ (max. value – min. value) = (1.903-1)/ (4-1) =0.301

**Step 2**. Calculating dimension value (repeat for other dimensions)

$M_{ada.cap}$ = (0.301 +0.417+0.359+0.774+0.55)/5 =0.481

**Step 3**. Calculating Potential impact (repeat for all livelihood assets)

$PI_{Human\ capital}$ = (Exposure + Sensitivity)/2 =(0.027+0.406)/2 = 0.216

**Step 4**. Calculating LVI-IPCC (repeat for all livelihood assets)

$LVI\text{-}IPCC_{Human\ capital}$ =[ $PI_{Human\ capital}$ +(1-Adaptive capacity)]/2 = [0.216+(1-0.481)]/2 = 0.368

# Chapter 4: Evaluating WTA (willingness to accept) a subsidy for getting a VietGAP certificate in shrimp farming: A case study in Tra Vinh province, Vietnam.


**Abstract**

Along with the developing shrimp industry, environment pollution problems and food safety are also important concerns. To develop shrimp farming sustainably, an eco-environment certification is often considered by stakeholders (government, exporters and farmers). This paper explored the benefits and limitations of the current incentive scheme of the VietGAP certification. And by using the contingent valuation method, this study surveyed 300 shrimp farmers in 10 villages in Tra Vinh province to find out what factors affect the farmers' decisions on following the VietGAP certification ($WTA_{Decision}$) and how much subsidy value they are willing to accept ($WTA_{Subsidy}$) to pursue the VietGAP standard. The results showed that $WTA_{Decision}$ had a positive relationship with farmers' education levels, environmental perceptions and attitudes toward the VietGAP certificate. While those factors had negative effects on $WTA_{Subsidy}$. Annual income also had a slight effect on amount subsidy farmers' willingness to accept. The study's findings suggest that the authorities should increase the subsidy at the first phase of scheme and improve the farmers' environmental perceptions and publicise the benefits of the VietGAP certificate to attract farmers to participate in it.


## 4.1 Introduction

Since 1990 the brackish shrimp industry has been in development and now plays a vital role in Vietnam's aquaculture sector. In the past 30 years, the brackish shrimp practice was thriving significantly in both horizontal and vertical dimensions. The shrimp industry is more and more intensified: from extensive to super-intensive practices. The impressive results are thanks to changing technology, methodology and species that are compatible with the seasons, environmental conditions and market demand. There are many shrimp export companies, which have promoted shrimp products, accounting for an average of 43.9% of total aquaculture exports in recent years. The related authorities supported shrimp farmers through training courses where they can learn about environment fluctuation and diseases. However, an increase in density of stock and expanding area caused some uncontrollable problems like disease outbreaks, polluted water resources, abuse of drugs and chemicals in shrimp practice. Overuse of drugs and chemicals is not only harmful to natural ecosystems but also affects customers' health due to the residual substances in shrimp products. This adversely affected the image of Vietnam's aquatic products on the international market. According to MARD, in recent years shrimp export products have been rejected by many importers due to food security issues and residual antibiotics. Therefore, Vietnam's shrimp industry is finding it difficult to penetrate new foreign markets. For instance, now 100% of shrimp shipments from Vietnam must be inspected by Japan's customs authorities, instead of testing 30% of the volume as usual; and Korea has also dispatched a warning about the presence of residual *Nitrofurans* in Vietnam's shrimp products (VASEP, 2020).

The aquatic industry in Vietnam developed dramatically. But its quick rise to prominence led to a polluted environment, disease outbreaks and affectedness of export aquatic quality. According to MARD (2015), for semi-intensive and intensive shrimp farming systems, each 1 kg of shrimp production discharges 1.12 kg solid effluence in the environment, not including other contaminated substances such as $H_2S$, $NH_3$ and phosphoric. Hence, the annual total solid effluence is estimated at more than 700,000 tons in the Mekong Delta, where accounts for 90% of the total national shrimp production. The Tra Vinh shrimp industry had an area of 32,976 ha and 55,330 tons in 2019, accounting for approximately 8% of the Mekong Delta's productivity (Aquaculture Department of Tra Vinh province). It means that a significant volume of that discharge was from shrimp production. Moreover, 40% of surveyed shrimp farms are without reservation ponds for treating wastewater. So, the current environment could get worse, which adversely affects shrimp health and causes disease outbreaks and crop loss. Environmental management and epidemic disease control are still neglected. Thus, the state of mass mortality has been ongoing in many farms in recent years, driven by several causes such as shortage of environmental testing systems, improper shrimp farming systems, low quality of seed, crop timetables not followed and so on. To mitigate the risk of crop loss due to disease outbreaks, most shrimp farmers rely on heavy use of chemicals, many of which are used improperly and end up contaminating the shrimp products. This leads to a loss of trust from customers, especially international importers. Shrimp farmed in Vietnam has difficulty penetrating tightly controlled markets like Japan and

Europe. Under the VietGAP standard, the quality of wastewater from shrimp ponds must achieve the indexes stated in Table 4.1. The actual status of wastewater of non-VietGAP shrimp farming was outside the permitted levels of the VietGAP standard. Hence, the application of VietGAP in shrimp farming is essential for preserving the environment.

**Table 4.1. Quality of discharge water permitted by the VietGAP standard**

| **Indicators** | **Unit** | **Permitted value (1)** | **Actual value (2)** |
|---|---|---|---|
| $NH_3$ (ammonia) | mg/l | <=0.3 | 0.7 (0.56-0.84) |
| $PO_4^{3-}$ (Phosphate ion or *Orthophosphate*) | mg/l | <10 | n.a. |
| $H_2S$ (Hydrogen sulfide) | mg/l | <=0.05 | n.a. |
| $NO_2$ (Nitrogen dioxide) | mg/l | <0.35 | n.a. |
| $BOD_5$ (Biochemical oxygen demand) | mg/l | <30 | 41 (22-59) |

*(1) The permitted value of VietGAP standard. (2) The actual value of intensive shrimp farming (non-VietGAP) in Can Gio district, Ho Chi Minh City, Vietnam (Anh et al., 2010).*

Hence, in 2011 the Ministry of Agricultural and Rural Development (MARD) promulgated the Vietnam Good Aquaculture Practice (VietGAP) standard to address the aquatic industry's sustainable development. The VietGAP is the guideline of aquaculture practice comprising five fundamental criteria: safe food, safe shrimp, safe environment, social responsibility and traceability information. The core of VietGAP is the list of criteria relating to ecological and environmental requirements adopted by the process of shrimp farming. The purpose is to maximise the regulatory functions of nature by making environmental conditions as favourable as possible for the sustainable development of shrimp farming. VietGAP has joined the Global Aquaculture Alliance (GAA), the Aquaculture Stewardship Council (ASC) and GlobalGAP. VietGAP is also looking forward to a collaboration with GlobalGAP to be recognised in the international market (Angus McEwin et al., 2014). Although by now it is still recognised in the domestic market and not yet accepted in international export markets, the quality of shrimp products under the VietGAP would meet all requirements of import countries. The content of VietGAP is similar to other international aquatic certificates which control the process of farming, from the inputs like seed, food, chemicals and water use to output like wastewater and product quality (shrimp, catfish, etc.). However, the cost of VietGAP certification is much lower than other certifications. For instance, the costs of the MSC (Marine Stewardship Council) certificate is US$100,000, about US$4,000 for ASC (Aquaculture Stewardship Council) and US$5,000 USD for the GlobalGAP certificate. Moreover, there are several benefits VietGAP offers to all stakeholders including farmers, exporters and customers. At present, the government encourages farmers to apply for the VietGAP standard in shrimp farming. Specifically, there were several promulgated documents such as Circulate No. 48/2012/TT-BNNPTNT dated 26 September 2012, Decision No. 4835/QĐ-BNN-TCTS dated 24 November 2015 promulgated by the Ministry of Agriculture and Rural Development (MARD), and Decision No. 28/2015/QĐ-UBND dated 9 November 2015 of People's Committee of Tra Vinh province. These decisions approved the policy of supporting and subsidising shrimp farmers who want to apply for the VietGAP standard. Because of limited budget for the subsidy scheme, the purpose of this scheme encourages the big farms (minimum 5ha farm-size) participate into VietGAP in the initial stage, afterward the small-scale farms would be inspired by the successful pioneers to volunteer applying VietGAP. However, over more than 8 years the number of farms got VietGAP certificate was still modest (with only 128 shrimp farms in national total [vietgap.tongcucthuysan.gov.vn]). In particular, currently there is only one shrimp farmer getting a VietGAP certificate in Tra Vinh province. It is far different to the MARD's expectation that 80% of shrimp farmers would apply for the VietGAP certificate by 2020. Whereas, the environment is more and more affected seriously by uncontrollable wastewater, abusing chemicals; and other problems mentioned above. Hence, it is necessary to promote the application VietGAP as soon as possible.

With a hypothesis of dropping the farm-size (5ha) criterion, the aims of the study are to determine the main factors influencing a farmer's decision whether to accept a subsidy for the VietGAP certificate and to estimate an expected minimum subsidy value for investment in construction, facilities and equipment for shrimp farms under the VietGAP standard. This study will also suggest some solutions for the successful application of this standard.

## 4.2 Literature and methodology

### 4.2.1 Literature

**Benefits of VietGAP standard**

If a shrimp farmer gets a VietGAP certificate, it means then that his shrimp satisfied the criteria for exporting markets. The VietGAP farmers can command higher shrimp prices than the non-VietGAP shrimp farmers. The discrepancy of the price is about 0.14 USD/kg for the average size of 79 individuals per kg (Quyen et al., 2020). The VietGAP farming system improves shrimp farmers' prestige and customers' trust due to reinforced food security. Hence, there are always plenty of aquaculture exporter companies that are ready and waiting for hedging all these products. Moreover, under the VietGAP standard, the farmers could reduce farming costs with good management of input costs like food and chemicals. And farmers would decrease the risk of disease outbreaks and preserve the environment with properly treated wastewater. According to Quyen et al. (2020), VietGAP shrimp farmers reported have fewer shrimp diseases than non-VietGAP shrimp farmers as well as lower probability of crop loss. VietGAP helps shrimp farming practices become not only stable and profitable but also enhances positive externalities such as improving Vietnam's image in the international market, promotion of a friendly environment in farming, restoring and reserving ecosystems around shrimp areas, which avoids conflicts between agricultural and aquaculture sectors.

Besides, shrimp processors save time and money on testing the input shrimp samples if they have quality materials that meet required standards from importers. They mitigate the risk of having their shipments rejected due to violations of antibiotic residue or related food safety issues. In addition, a VietGAP certificate also creates traceability information for shrimp products; this is also one of the requirements of import countries.

The VietGAP farmers would help create a positive image of Vietnam's shrimp products. When the shrimp product is accepted in the wider world, this helps the Vietnamese economy become increasingly integrated with international economies. Applying for the VietGAP certificate in farming would change the traditional aquaculture practice and would give farmers an image of environmental responsibility and social health. This contributes to the quality of social life and sustainable development. The value of this certificate is not only in its economic aspects but also indicates the farmer's responsibility in terms of environmental conservation in the future and at present for himself. The certificate is also a requirement for the sustainability of shrimp farming. Finally, customers feel secure to use safe, quality shrimp products, which is the core aim of the VietGAP standard.

Although the incentive scheme began in 2015, as stated before there is currently only one farmer getting a VietGAP certificate in Tra Vinh province. Below is the story of the pioneer farmer who pursued VietGAP successfully.

*Le Van Hoc, who owns more than 5ha of shrimp farms located in Thanh Hoa Son hamlet, Cau Ngang district, Tra Vinh province. He is a young man, 34 years old, with a high school education. He started shrimp farming in 2011 with a 1ha shrimp farm which he inherited from his father. After many years of success with intensive shrimp practice, he bought adjacent land around his farms to expand his farm's area. With the purpose of achieving the VietGAP certificate, all of his current facilities met the VietGAP standard, with the exception of the farm area being less than 5ha, to get the subsidy from the Tra Vinh authority. In 2017 his brother left him more than 1ha of shrimp ponds. At last, his farm area met the requirements for VietGAP's subsidy scheme. He got a VietGAP certificate at the end of 2018, and after one year he looked into the procedure for submitting to the provincial authority. He said that farming under the VietGAP plan is not as difficult as many farmers' think. There were many farms around his that could meet a part of or completely fulfil the VietGAP standard. The main drawback that causes shrimp farmers to be afraid of participating in VietGAP is that it is a complicated procedure that requires much documentation, which is not their strong point. The current benefits of the VietGAP farming system are the first-time subsidy investment costs and being offered higher shrimp prices than non-VietGAP shrimp from collector or processor shrimp businesses. In the long term, it is a positive trend of sustainable shrimp farming because of the lighter impact on the environment and increased food safety. Based on his actual practice costs, the farmer revealed that the average costs of construction, facilities and equipment is approximately 70 million VND per 1,000* $m^2$ *for the VietGAP standard compared to about 30 million VND for non-VietGAP standard.*

**The current incentive subsidy scheme for application VietGAP standard**

To encourage shrimp farmers to work toward sustainable development, Tra Vinh authority approved the policy of supporting and subsidising shrimp farmers who want to apply for the VietGAP standard (Decision No. 28/2015/QĐ-UBND). If the shrimp farmer gets a VietGAP certificate, they would receive four categories of subsidy as follows.

Sub1: Subsidy for 100% of the fee for examination of land and water. The fee is not excess of 5 million VND (approximately 200 EUR).

Sub2: Subsidy for 50% of the post-larvae cost and 30% of the costs of building, reconstructing ponds and warehouse (where stores food, medicines and medicals), machines and other facilities, toilets, sewage systems, waste treatment systems based on the VietGAP standard. Total cost does not exceed 150 million VND/household (approximately 5,700 EUR).

Sub3: Subsidy for 100% of the first-time training and consulting fee. The total fee does not exceed 40 million VND/household (approximately 1,500 EUR).

Sub4: Subsidy for 100% of the fee for an organisation responsible for testing for and issuing a certificate of VietGAP.

According to Sub2, the maximum subsidy value for costs of construction, facilities and equipment is always less than 150 million VND per farm. But the minimum required farm size to apply for this incentive program is 5ha. Hence, farmers could get a maximum subsidy for those costs lower than 30 million VND per ha or 3 million VND per 1,000 $m^2$. While the average costs of construction (ponds, warehouse, sewage system, wastewater treatment system), facilities and equipment (aeration fans, electric line, machines, etc.) under VietGAP standard is approximately 70 million VND per 1,000 $m^2$ (0.1 ha). This number is provided by a pioneer VietGAP farmer. Therefore, this study focuses on this category of subsidy (Sub2) to investigate how much a minimum subsidy the shrimp farmers are willing to accept within threshold of 70 million VND per 1,000 $m^2$. According to expert opinions, the other categories of subsidy are quite reasonable.

**The process of getting a subsidy for VietGAP certificate**

Fig. 4.1 illustrates the process of getting a subsidy for VietGAP certification. There are four stakeholders in this process that are farmer, authority, VietGAP consultant and VietGAP certified organisation.

The first step is that shrimp farmers must have a minimum farm size of 5ha. To register for the VietGAP farming system, the farmers can contact the VietGAP consultant or themselves to prepare all required documents for submission to the local district or city authority.

In the second step, shrimp farmers contact the Department of Quality Management of Agriculture-Forest-Aquatic, Department of Aquaculture and the VietGAP consultant to come up with the quality management system and participate in the VietGAP training courses. Then the farms must be reconfigured to conform to VietGAP requirements.

The third step is that farmers apply the quality management system in practice. The farmers gather all documentation relating to farming activities such as invoices for seeds, food, chemicals, aquatic drugs, labour contracts and so on. After that, someone from the VietGAP organisation is invited to inspect the farming methods and certify that they meet VietGAP standards. In the final step, shrimp farmers prepare the necessary documents to apply for a subsidy from the district authority.

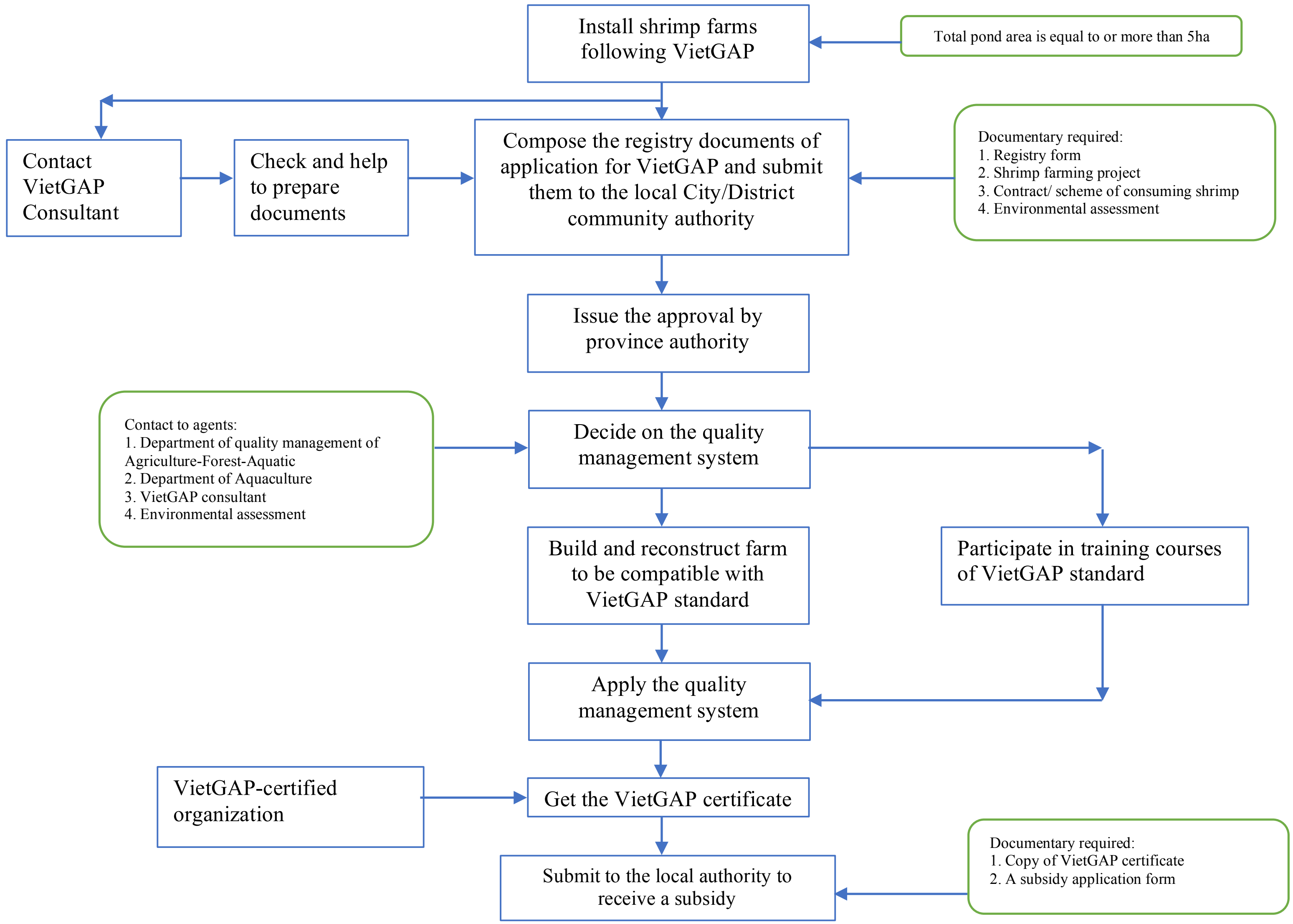



**Figure 4.1 The process of getting a subsidy for VietGAP certificate in shrimp farming.**

*Source:* Department of Science and Technology & Center for Statistics and Science and Techonology Information of Tra Vinh province.

### 4.2.2 Methodology

This study employed the contingent valuation method (CVM) to investigate shrimp farmers' willingness to accept a subsidy value for applying the VietGAP standard in shrimp farming. This method is the standard measure for the value of the environment and natural resources which are non-marketed goods and services. To elicit valuation under the CVM, there are four widely used formats such as open-ended questions, bidding game, payment card and single- or double-bounded dichotomous choice (Pearce et al., 2002). Each elicitation format has its own advantages and disadvantages, but all of them require the respondents to pay money for benefits (willingness to pay-WTP) or accept money for changing (willingness to accept-WTA). In this study, VietGAP is innovative method should be applied in shrimp farming, so the government encourages shrimp farmers apply it (changing the current method farming to VietGAP farming) and offers them a subsidy. Hence, the study use WTA to know a minimum of subsidy that farmers require to adopt VietGAP.

The study used open-ended questions to find out from shrimp farmers how much a minimum subsidy they require to adopt VietGAP standards. Although this choice of format is simpler than others, it allows the respondents some flexibility in gauging the amounts they need without trapping bias by given amounts (Pearce et al., 2002). Hence, they offered reliable values for the research. Because the questionnaire provided the information of the VietGAP standard relating to the current incentive subsidy for application of VietGAP standard from the government, as well as the estimated average investment costs of construction, facilities and equipment per hectare under the VietGAP standard (as mentioned above section). Therefore, the farmers find it easy to calculate the additional investment costs basing on their existing farming method compared to the VietGAP standard. Moreover, the open-ended questions are also suitable for shrimp farmers who have little time for interfacing with an interviewer.

### 4.2.3 Survey design

In order to answer two major questions of the study investigating whether shrimp farmers are willing to accept the changeover from traditional shrimp farming systems to the VietGAP standard, and a minimum subsidy they require to conform with the VietGAP standard, a direct face-to-face interview was carried out. The

VietGAP standard might be unfamiliar to the majority of shrimp farmers, thus before starting the survey, the interviewers have to introduce the basic information related to the VietGAP and the current incentive, as well as explain the benefits of it to respondents.

In order to guarantee that the questionnaire is reliable, the trial survey was conducted to find out how comfortable respondents feel and to avoid the pressure of having to give accurate answers as well as to calculate the average time for completing the questionnaire. After the trial survey, some adjustments were made for the final questionnaire which consisted of four parts (appendix 4.A).

The first part explores farmers' personal characteristics, including age, shrimp-farming experience, average annual income, farm size and education of respondents which are detailed in many articles such as He et al. (2016), Xie et al. (2017), Zheng et al. (2019) and Wang et al., (2020).

In part 2, farmers' environmental perspectives were measured by two observation variables that include: current status of polluted water resources (1= definitely not polluted, 2= slightly polluted, 3= generally polluted, 4= highly polluted, 5= very high polluted); and a question on whether shrimp farming is the main cause of polluted river water (1=strongly disagree; 2=disagree; 3= neither agree nor disagree; 4= agree; 5= strongly agree). This environmental questionnaire was used to measure respondents' assessment of the condition of the environment. This is the factor that gauges a farmer's willingness to pay for improving or accepting compensation for changing their farming techniques. This factor variable was also used by He et al. (2016) and Zheng et al. (2019).

Part 3 explored the farmers' attitudes toward the VietGAP standard with four questions relating to an increase in the price of shrimp, contribution to sustainable shrimp farming, enhancing shrimp exporting, and benefit to the environment (a five-point Likert scale was used for the four questions, 1=strongly disagree; 2=disagree; 3=neither agree nor disagree; 4=agree; 5=strongly agree). This factor reflects respondents' intentions to adopt an innovative technology (He at al., 2016) and whether they will adopt the VietGAP standard (Tinh et al., 2019).

Part 4 looks at respondents' WTA for VietGAP. With a hypothesis that the subsidy scheme of VietGAP drops out the criterion of farm size (5ha). The government would support finance to farmers who adopt VietGAP standard in shrimp farming. There are two main questions in this section. The first question relates to whether the respondents are willing to accept a subsidy for VietGAP certification or not. The question is: *"Would you be willing to accept the subsidy scheme for changing from traditional farming system to VietGAP?"* If the answer is yes, the survey would continue with the second question, which is: *"Suppose that total costs of investment of construction and all necessary facilities, equipment under VietGAP standards about 70 million VND per 1,000 $m^2$ of shrimp pond. How much a minimum amount of subsidy would you be willing to accept to do shrimp farming under VietGAP standard?"* This is to find out the minimum amount of subsidy required.

### 4.2.4 Estimation methods

**Regression for household's WTA a subsidy for VietGAP standard ($WTA_{Decision}$)**

In analysing factors affecting farmers' decisions on the willingness to accept ($WTA_{Decision}$) a scheme subsidy for implementation of the VietGAP standard in shrimp farming, the maximum likelihood estimation (MLE) was employed to estimate the parameters with a binary regression. And the log-likelihood function (binary logit regression model) is denoted as follows:

$WTA_{Decision}$ = 1 with probability is P

$WTA_{Decision}$ = 0 with probability is (1-P)

$$P = \frac{e^{a + ßkXki + µi}}{1 + e^{a + ßkXki + µi}}$$

$$1 - P = 1 - \frac{e^{a + ßkXki + µi}}{1 + e^{a + ßkXki + µi}} = \frac{1}{1 + e^{a + ßkXki + µi}}$$

$$\text{Odds} = \frac{P}{1-P} = e^{a + ßkXki + µi}$$

$$\text{Ln(Odds)} = \text{Ln}\left(\frac{P}{1-P}\right) = a + ß_k X_{ki} + µ_i$$

$P_i$ is the probability of respondent $i^{th}$ willing to accept a subsidy scheme for following the VietGAP standard.

$\frac{P}{1-P}$ is an odds of the probability of WTA a scheme subsidy for VietGAP compared to the probability of not WTA of respondent $i^{th}$.

$X_{ki}$ are the explanatory variables, which include respondents' characteristics, environmental perception and attitudes toward the VietGAP standard.

a is the intercept parameter.

$ß_k$ is coefficient of $X_{ki}$ that affects on the Ln(odds) or the log-odds

When $X_k$ increases one-unit ($X_k$ +1), then:

$X_k \rightarrow Ln(odds_1) = a + ß_k X_{ki} + \mu_i$

$X_k + 1 \rightarrow Ln(odds_2) = a + ß_k (X_{ki} + 1) + \mu_i = Ln(odds_1) + ß_k$

$ß_k = Ln(odds_2) - Ln(odds_1) = Ln(\frac{odds2}{odds1})$

$\frac{odds2}{odds1} = e^{ßk} \rightarrow odds_2 = e^{ßk} * odds_1$

Therefore, when $X_k$ increases one-unit ($X_k$ +1), the odds of WTA a scheme subsidy for VietGAP would change $e^{ßk}$ times.

$\mu_i$ is the residue consisted of other unobserved variables.

**Regression for household's WTA the value of subsidy for farming under the VietGAP standard ($WTA_{Subsidy}$)**

The OLS (Ordinary Least Squares) regression used to estimate the parameters affecting the minimum amount of subsidy required by shrimp farmers.

$WTA^i_{Subsidy} = a + ß_k X_{ki} + \mu_i$

$WTA^i_{Subsidy}$ = the accepted value of subsidy for costs of investing in construction and all necessary facilities, equipment under VietGAP standard.

$X_{ki}$ are the explanatory variables, which encompasses respondents' characteristics, environmental perception and attitudes towards the VietGAP standard.

$ß_k$ is estimated parameter.

a is the intercept parameter.

### 4.3 Results

The study was conducted with a total of 300 shrimp farmers in 10 villages in two districts of Tra Vinh province. There were about 30 respondents surveyed randomly in each village. The study started at the beginning of December 2018 and was finished by the end of January 2019.

#### 4.3.1 Statistical description of farmers' characteristics

Of the 300 farmers surveyed (Table 4.2), the age of the respondents ranged from 24 to 66 years old, whereas 31% were over 50 years old, 44.33% of them were in the 41 to 50 age group, and the members of the remaining group were under 40 years old. Average years of experience in shrimp farming was approximately 7 years. Only

10% of shrimp farmers had more than 10 years' experience. A majority of them (54%) had between 6 and 10 years' experience, and a lower percentage (36%) had no more than 6 years' experience. In terms of education, the largest proportion consisted of farmers who had secondary school degrees (43.33%). Farmers with a primary school education came second (33.33%), and a modest percentage had a high school education (23.33%). So, it could be considered an advantage in being young and literate, as these types of people can often relate to environmental responsibility. The average shrimp production area was approximately 1.6 ha with a minimum of 0.1 ha and a maximum of 16 ha. A majority of shrimp farmers operate on a smaller scale, and the survey data recorded that 59% of households own a farm size of less than 0.5 ha, while households with 0.6-2 ha of farm size accounted for 13%, and the remaining 28% of households had a farm size from 2 ha to 5 ha. In terms of household annual income, the survey showed that the mean was 130 million VND (equivalent to 5,000 EUR, reference exchange rate of 26,000 VND/EUR). The annual income distribution ranged between 20 million VND and 600 million VND. Forty percent of shrimp farmers had yearly incomes of 51 to 100 million, and 33% had incomes of 101 to 200 million VND, respectively. The lowest and highest household groups accounted for a minority proportion, with 14.33% and 12.67% respectively.

### 4.3.2 Farmers' environmental perception

With regard to environmental perception, shrimp farmers mostly believed that, in general, highly polluted water resources accounted for 42% and 38% of the total samples. The remaining supposed that it was inconsiderably polluted. In general, shrimp farmers were aware of the adverse environmental conditions surrounding their farms. However, a minority of farmers (14%) agreed that polluted river water was mainly due to shrimp farming. The rest of the farmers surveyed were not sure or did not agree with this result (Table 4.2). Water resources can become polluted from shrimp farming, rice farming, fish farming, vegetable farming, residential areas and so on. However, shrimp farming is the main cause of polluted water in rivers or canals around shrimp-farming areas (MARD, 2015). Shrimp farmers might not recognise all the contaminated substances in wastewater from shrimp ponds. While the survey recorded that 40% of farms were without reservation ponds for treating discharge water, the remaining farms fulfilled the treatment without a post-test for safety limitations of discharge water.

### 4.3.3 Farmers' attitudes towards VietGAP standard

With respect to farmers' attitudes towards the VietGAP standard, there are four main observations. The surveyed shrimp farmers mostly expressed agreement or strong agreement with the benefits gained from the implementation of VietGAP standard with regard to environmental preservation principles, the sustainability of shrimp farming and the prospect of easily exporting shrimp as well as fetching higher shrimp prices if the VietGAP certificate is obtained (Table 4.2). Specifically, 80% of respondents believed VietGAP farming would be beneficial to the environment or promote sustainable shrimp farming in the future. In terms of shrimp price, 81% of surveyed farmers agreed and strongly agreed with the benefits of higher shrimp prices with VietGAP farming compared to non-VietGAP farming. According to Baumgartner et al. (2016), 57.5% of shrimp farmers' opinions on higher shrimp prices are under the eco-environmental certification.

Almost the surveyed shrimp farmers agreed that VietGAP's shrimp would meet the export criteria. They also knew the required criteria for exportation of shrimp: no overuse of antibiotics, as well as acceptable-sized and healthy-looking shrimp. And they believed that VietGAP certification will bring them benefits relating to the environment, economics and sustainability.

**Table 4.2. Descriptive statistics**

| Variables | Mean | Category | Sample | Percentage (%) |
|---|---|---|---|---|
| Age (year age) | 46.5 | <=40 | 74 | 24.67 |
| | | 41-50 | 133 | 44.33 |
| | | >50 | 93 | 31 |
| Education of respondents | 1.9 | 1 (primary school) | 100 | 33.33 |
| | | 2 (secondary school) | 130 | 43.33 |
| | | 3 (high school) | 70 | 23.33 |
| Experience (year) | 7.2 | <=5 | 108 | 36 |
| | | 6-10 | 162 | 54 |
| | | 11-20 | 30 | 10 |
| Farm size (hectare) | 1.6 | <0.5 ha | 177 | 59 |
| | | 0.6-2 ha | 39 | 13 |
| | | 2h-4.9 ha | 58 | 19 |

| | | | | |
|---|---|---|---|---|
| | | >=5 ha | 26 | 9 |
| Average annual income (million VND) | 130 | 20-50 | 43 | 14.33 |
| | | 51-100 | 120 | 40 |
| | | 101-200 | 99 | 33 |
| | | 201-600 | 38 | 12.67 |
| Shrimp farming is a main cause of polluted river water (a five-point Likert scale) | 2.75 | <3 | 102 | 34 |
| | | 3 | 156 | 52 |
| | | >3 | 42 | 14 |
| Degree of polluted river water (a five-point Likert scale) | 3.2 | <3 | 60 | 20 |
| | | 3 | 126 | 42 |
| | | >3 | 114 | 38 |
| VietGAP standard is beneficial to environment (a five-point Likert scale) | 4.16 | 3 | 53 | 17.67 |
| | | 4 | 145 | 48.33 |
| | | 5 | 102 | 34 |
| VietGAP standard contributes to sustainable shrimp farming (a five-point Likert scale) | 4.3 | 3 | 47 | 15.66 |
| | | 4 | 107 | 35.67 |
| | | 5 | 146 | 47.67 |
| VietGAP certificate helps to improve exporting of shrimp (a five-point Likert scale) | 4.24 | 3 | 54 | 18 |
| | | 4 | 118 | 39.33 |
| | | 5 | 128 | 42.67 |
| Shrimp price is higher with VietGAP standard (a five-point Likert scale) | 4.2 | 2 | 11 | 3.67 |
| | | 3 | 44 | 14.67 |
| | | 4 | 120 | 40 |
| | | 5 | 125 | 41.66 |
| $WTA_{Decision}$ (yes/no) | | Without willingness | 72 | 24 |
| | | Willingness | 228 | 76 |
| $WTA_{Subsidy}$ (Million VND/0.1 ha) | 20.4 | <20 | 62 | 27.19 |
| | | 20 | 88 | 38.6 |
| | | 25 | 51 | 22.37 |
| | | 26-40 | 27 | 11.84 |

#### 4.3.4 Descriptive $WTA_{Decision}$ and $WTA_{Subsidy}$

The survey recorded 72 shrimp farmers (30 extensive farmers; 14 semi-intensive farmers, and 28 intensive farmers) who were unwilling to accept a subsidy to follow the VietGAP standard, which accounted for 24% of interviewed households. The main reasons for this reluctance to adopt the VietGAP were revealed. Firstly, majority of them are with a small farm size, there is not enough area for a reservation pond as required by VietGAP standards. However, there are 20 extensive farms equal to and over 5ha that is satisfied with the VietGAP criteria, but they found it difficult with financial problems. If they follow the VietGAP standard, they have to invest a large amount of money than that of two other systems. Because infrastructure of extensive farming system is simple and low initial cost investment. While VietGAP standard requires the basic investment is more compatible with the semi-intensive or intensive farming systems. Secondly, some of the farmers thought that the difference between the shrimp prices commanded by VietGAP farming compared with non-VietGAP farming was insignificant, while the investment cost was prohibitively higher for refurbishing the farm according to the VietGAP standard. The average costs of construction, facilities and equipment for conventional farming systems are from 20 to 30 million VND per 1,000 $m^2$ (MARD, 2015; JICA, 2013; survey data), while the average costs of those for VietGAP farming systems are approximately 70 million per 1,000 $m^2$ (a VietGAP farmer provided). Thirdly, these farmers were afraid of VietGAP standards being not applied consistently the in the same areas, which would be difficult to make controlling the common environment. Lastly, a lack of information related to VietGAP standards caused some farmers to lose interest in the idea.

In contrast, total of 228 (76%) farmers (13 extensive farmers; 48 semi-intensive farmers, and 167 intensive farmers) were willing to accept the VietGAP standard with a specific subsidy, but only 6 extensive farms are equal to or over 5ha meeting the VietGAP criteria, the remaining semi-intensive and intensive farms are smaller than 5ha. Although almost them are small size, with inspired environmental responsibility, expected high shrimp prices, and support from the government they would like to apply VietGAP standard in shrimp farming. Furthermore, they expect the new shrimp process help them control disease better than the current systems.

The data reported that the expected amount of the subsidy ranged from 10 to 40 million VND per 1,000 $m^2$ (0.1 ha) compared to the projected cost of 70 million

VND per 1,000 $m^2$. Farmers willing to accept a subsidy of 20 million VND accounted for 38.6% of the total, and 27.19% of farmers accepted lower than 20 million VND. The sum of 25 million VND was also accepted by 22.37% of respondents. The small remaining percentage had a WTA subsidy range of 26 to 40 million VND (Table 4.2). The difference in investment costs between VietGAP farming and non-VietGAP farming is approximately 40 million VND. Therefore, it is reasonable for the maximum subsidy amount required by the shrimp farmers.

### 4.3.5 Estimating results and discussion

The study used Stata MP version 14.0 to run a regression test, and the results are stated in Table 4.3.

**Table 4.3. Result of regression $WTA_{Decision}$ and $WTA_{Subsidy}$ for VietGAP**

| VARIABLES | $WTA_{Decision}$ | $WTA_{Subsidy}$ |
|---|---|---|
| Age | -0.0467 | 0.00104 |
| | (0.0377) | (0.0386) |
| Education | 0.875* | -2.563*** |
| | (0.496) | (0.435) |
| Experience | 0.0601 | 0.151 |
| | (0.0857) | (0.0968) |
| Farm size | -1.88e-05 | 6.16e-06 |
| | (1.47e-05) | (2.27e-05) |
| Income | 0.00701 | -0.0309*** |
| | (0.00593) | (0.00364) |
| Env_perception | 2.047*** | -1.344*** |
| | (0.579) | (0.492) |
| Attitude | 5.330*** | -2.569*** |
| | (0.743) | (0.952) |
| Constant | -26.08*** | 44.25*** |
| | (4.460) | (4.739) |
| Observations | 300 | 228 |
| R-squared | | 0.437 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Cronbach's Alpha test was conducted to analyse the reliability of the scale of two qualitative variables: environmental perception (Env_perception) and attitude toward VietGAP standard (Attitude). The result showed that the scale reliability coefficients were 0.7 for the 'Env_perception' variable and 0.83 for the 'Attitude' variable, which were reliable at more than 0.6 (Nunnally, J. and Brunstein, 1994). Moreover, all observation variables had an item rest correlation >0.4 which means they are high correlation with each other in the factor variables (Appendix 4.A). Therefore, no observation variable was omitted.

To guarantee all independent variables are not collinear with each other, a multicollinearity test was used to calculate the variance inflation factor (VIF) for both MLE and OLS regressions. The results showed that VIF=1.24 and 1.15 for the MLE and OLS estimate, respectively. There was no multicollinearity found between explanatory variables. Besides, test of correction prediction of logistic model stated that the model predicts correction of 96.3% (Appendix 4.A).

In this chapter, the two dependent variables are the shrimp farmers' WTA in participating VietGAP ($WTA_{Decision}$) and the shrimp farmers' WTA amount subsidy for a VietGAP certificate ($WTA_{Subsidy}$). Table 4.3 shows that both households' $WTA_{Decision}$ and households' $WTA_{Subsidy}$ were significantly influenced by education, environmental perceptions and attitudes toward VietGAP. Moreover, households' $WTA_{Subsidy}$ also correlated with annual average income. The remaining factors such as age, experience and farm size did not affect the $WTA_{Decision}$ or $WTA_{Subsidy}$.

The result showed that education has a positive, significant influence on farmers' $WTA_{Decision}$, which means that highly educated respondents are more probability to participate in the VietGAP standard certification, ceteris paribus. For every one-unit increases in education, for example going from primary school degree to secondary school degree, we expect a 0.875 increase in the log-odds of the dependent variable ($WTA_{Decision}$) and holding all other independent variables constant. In other words, the odds of WTA a scheme subsidy for VietGAP would increase about 2.4 times [$odds\ ratio = \frac{odds2}{odds1} = e^{0.875}$ =2.4] if farmers' education increases one-unit (from primary school to secondary school, or from secondary school to high school), keeping all other independent variables unchanged. It could be said that higher educated farmers are more adventurous and easy to be take-riskers, pioneers in implicating a new technology into their work. They will also be more likely to integrate new technology into their work.

Furthermore, the more highly educated farmers were also willing to accept a smaller subsidy amount for the VietGAP standard than the less educated farmers, which is illustrated by a negative coefficient and significant level at 1% of the education variable in the $WTA_{Subsidy}$ regression. Specifically, farmers who have secondary shool degree would be willing to accept a decrease 2.563 million VND compared with farmers having primary school degree, ceteris paribus. And similar interpretation for high school farmers.

The annual average income has a negative coefficient and is significant at 1%, which implies that the required amount of subsidy would decrease 0.03 million VND if annual average income increases one million VND, with all other variables unchanged. In other words, if a farmer's annual income is more, he would be willing to accept a smaller subsidy for investment in construction, facilities and equipment under the VietGAP standard. Hence, the subsidy amount has a negative relationship with annual income.

Environmental perception has a positive impact on $WTA_{Decision}$ and a negative impact on $WTA_{Subsidy}$ at a significant level of 1%. Holding all other explanatory variables constant, if the environmental perception increases one point, the log-odds of $WTA_{Decision}$ would be expected to increase 2.047 or the odds of WTA a scheme subsidy for VietGAP would increase about 7.74 times [$odds\ ratio = \frac{odds2}{odds1} = e^{2.047} = 7.74$], and the accepted subsidy amount ($WTA_{Subsidy}$) would decrease 1.344 million VND for pursuing VietGAP. Shrimp farmers are more responsible for the environment, who believed that the current state of river water is a serious issue and that traditional shrimp farming activity had a negative effect on the environment in general. They had a stronger propensity to WTA participation in the VietGAP system and were generally willing to accept a smaller subsidy for VietGAP farming. A negative assessment of the environment could be seen as a pessimistic view, but it also could lead to more environmentally responsible actions and inspire farmers to change their behavior and farming processes to sustain their livelihoods.

Farmers' attitudes toward the VietGAP standard have a strong correlation and positive coefficient with $WTA_{Decision}$ but a negative coefficient with $WTA_{Subsidy}$. This result means that farmers are more interested in the benefits of the VietGAP standard, the higher probability of WTA participating in VietGAP and the lower subsidy required to follow the VietGAP standard. Specifically, if the attitudes toward increases one point, the log-odds of $WTA_{Decision}$ would be expected to increase 5.33 or the odds of WTA a scheme subsidy for VietGAP would increase about 206.3 times [$odds\ ratio = \frac{odds2}{odds1} = e^{5.33} = 206.3$], and the accepted subsidy amount ($WTA_{Subsidy}$) would decrease approximately 2.57 million VND for pursuing VietGAP, holding all other explanatory variables unchanged.

### 4.4 Extended discussion

#### 4.4.1 Drawbacks of applying the VietGAP standard

Although application for the VietGAP standard is encouraged, hardly any Vietnamese shrimp farmers have done so. They usually follow the processes of companies that supply formulated food or biochemical products used in aquaculture. Those companies prompted farmers to use their products as much as possible. As a result, use of chemicals and residual food not only led to higher farming costs but also posed a risk to the environment. There are obvious benefits from VietGAP, but an increase in investment costs under the VietGAP process dampened shrimp farmers' enthusiasm in applying for it. Although higher shrimp prices can be fetched under the VietGAP farming system than in non-VietGAP farming (Quyen et al., 2020), the cost of investing in construction, facilities and equipment is beyond the means of small-scale farmers. Moreover, the current incentive scheme of VietGAP only gives grants for farms 5 ha or larger, while more than 90% of shrimp farms have less than 5 ha of land in Tra Vinh province. Therefore, many small-scale farmers were not interested in obtaining the VietGAP standard. Another of the farmers' concerns is the fragmental application of VietGAP farms or a sole VietGAP farm located around non-VietGAP farms, which is a disadvantage for the VietGAP farms because of common water resource use. The current scheme of VietGAP certification seems unfavorable to small-scale shrimp producers because it requires compliance with several technical criteria such as a warehouse for storing food and chemicals and daily recorded documentation (Marschke et al., 2014). Those requirements are not necessary for small-scale farms because they could use their homes for food and chemical storage. In addition, the financial requirements may be an obstacle for small producers perusing this certificate (Quyen et al., 2020).

#### 4.4.2 Status quo of exporting shrimp

In the last five years, Vietnam shrimp export revenue achieved an average growth of 4.1% (VASEP, 2020). The three main global importers of Vietnamese shrimp are Japan, the EU and the US, who together accounted for approximately 60% of the total shrimp export value (Table 4.4). The EU was the biggest importer of Vietnamese shrimp, accounting for more than 20% annually. The export value has slightly fluctuated over the years, but in general, had an increasing trend. In particular, 2019 due to disease outbreak occurred in the first quarter causing small shrimp-size and lower export prices, and Vietnam was competitive from other exporters like India, Thailand, Indonesia, Malaysia and so on.

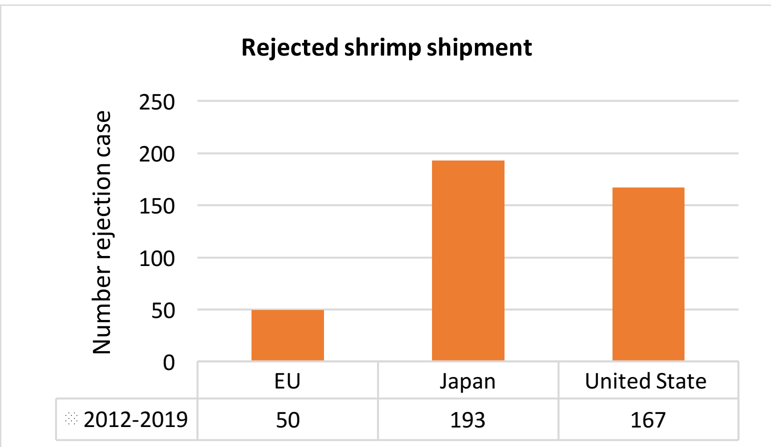
**Table 4.4. Three main shrimp import markets and total shrimp exports**

*Unit: million USD*

| Export value | 2015 | 2016 | 2017 | 2018 | 2019 | Average |
|---|---|---|---|---|---|---|
| EU | 548.6 | 600.4 | 862.8 | 837.8 | 696.2 | 709.2 |
| United States | 656.9 | 708.8 | 659.2 | 637.7 | 646.6 | 661.8 |
| Japan | 583.9 | 599.7 | 704.1 | 638.8 | 626.0 | 630.5 |
| Total shrimp exports | 2,950.0 | 3,150.0 | 3,850.0 | 3,550.0 | 3,380.0 | 3,304.0 |

*Source: VASEP, 2020. Report on Vietnam Shrimp Sector 2015-2019*

Besides the impressive export numbers, the shrimp export products were facing quality issues. According to Southern Shrimp Alliance, there has been a significant number of Vietnamese shrimp shipments rejected by three main importers in recent years (Fig. 4.2) because of hygienic and residual antibiotic problems. The main causes of these problems include abuse of chemicals and fertilizers as well as environmentally harmful drugs and antibiotics used in the aquaculture to increase productivity and adapt to adverse climate change fluctuations with regardless of harmful to environment or healthy human (Nhung et al., 2017; Zheng et al., 2019). As a result, residual antibiotics and chemicals may exceed the permitted threshold for importers.




*Source:* Southern Shrimp Alliance.

**Figure 4.2 Number of shrimp shipments rejected by three main importers from 2012 to 2019.**

From 2012 to 2019, there were many rejected shrimp transactions by the major markets. These rejections caused major financial losses but also loss of trust and negative perceptions of Vietnamese shrimp in international markets. To deal with those problems, a collaboration between processors and shrimp farmers is needed. The processer enterprises should offer a competitive price all products from farms having a quality certificate such as ASC, BAP, GlobalGAP or VietGAP. And harvesting shrimp with proper processes in order to ensure hygienic conditions and traceable information enhances companies' prestige and customer trust.

However, the forecasted demand for shrimp in those markets is still set to increase in the future. According to MARD (2015), and based on the data of FAO from the period 2013 to 2018, in 2020 demand for shrimp in America would be 643,000 tons, which would account for 15% of the total global demand (if its economy had not been affected by the coronavirus pandemic). In 2030 its demand is predicted to increase by 675,000 tons (Fig. 4.3). If Vietnam keeps the third rank of countries exporting shrimp to the US by 2030, it's export production will be able to reach approximately 202 thousand tons in 2030 (basing on the market share of period of 2010-2014, MARD (2015)).

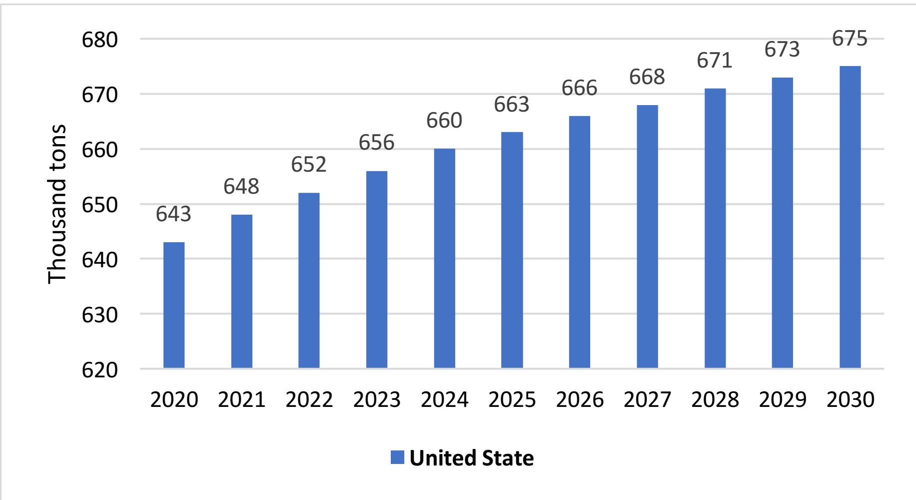



**Figure 4.3 Forecasted demand for shrimp in United States.**

*Source:* MARD, 2015. Calculation based on the FAO's data.

Similarly, European markets are also predicted to increase shrimp consumption gradually from 2020 to 2030 (Fig.4.4). The EU was the biggest importer of Vietnamese shrimp, accounting for more than 20% annually. So, Vietnamese shrimp has a big room in this market if it abides by the strict technical barriers (the permitted residual substances in shrimp products), and it is predicted to reach about 180 thousand tons in 2030.

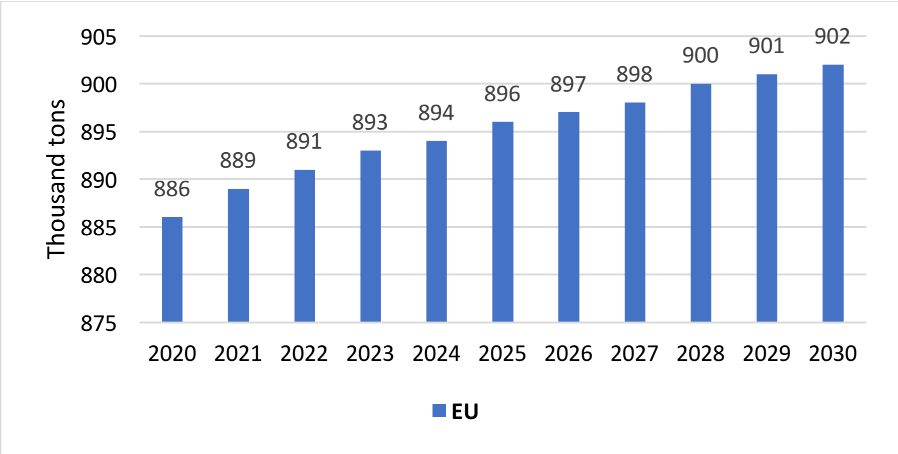



**Figure 4.4 Forecasted demand for shrimp in Europe.**

*Source:* MARD, 2015. Calculation based on the FAO's data.

While the demand of shrimp in Japan market is predicted to grow significantly with average 10% per year from 2020 to 2030 (Fig.4.5). However, this market has become cautious with Vietnamese shrimp due to breaches of quality in recent years. Hence, application of VietGAP in shrimp farming is an essential step forward to strict markets.

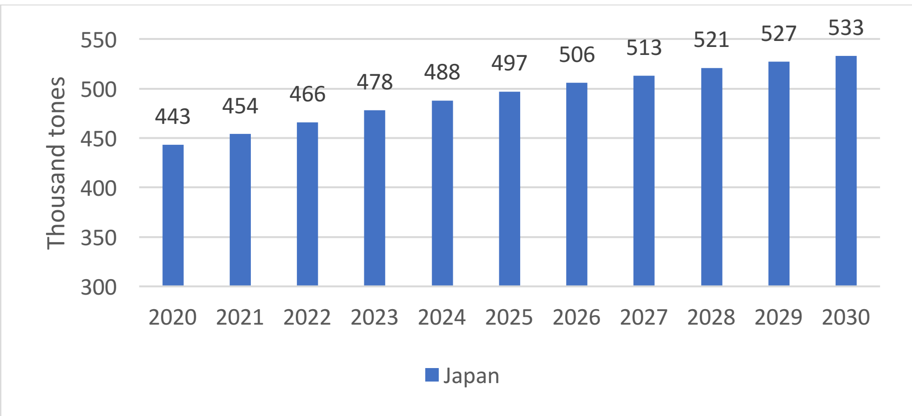



**Figure 4.5 Forecasted demand for shrimp in Japan.**

*Source:* MARD, 2015. Calculation based on the FAO's data.

In general, the demand of shrimp is predicted the trend will continue increasing in the future. Therefore, the VietGAP standard plays an important role in paving the way for Vietnamese shrimp to penetrate international markets. Although VietGAP is still not accepted internationally, it is a baseline for improving shrimp farmers' environmental perceptions, which is considered an essential milestone for international recognition.

## 4.5 Conclusion

The VietGAP certificate is worth obtaining not only for its positive economic aspects, but it also indicates the farmer's ongoing commitment to live up to requirements related to the sustainability of shrimp farming. The farmers would contribute to creating a good image of Vietnam's shrimp products under the VietGAP standard. When the shrimp product is accepted in the wider world, this helps the Vietnamese economy interact effectively with international economies. This study could conclude that the purpose of obtaining the VietGAP standard is not beneficial to shrimp farmers for short-term ambitions such as an increase in productivity, helping the financial bottom line or the shrimp being disease free. In the long term, however, farmers can have sustainable development in terms of environmental preservation, creating a good image and reputation and internationalising the VietGAP certification with a lower cost compared to other international certifications (ASC, GlobalGAP, etc.). Application of the VietGAP standard would help reduce the risk of rejected shrimp shipments and could secure potential import markets.

The study used the contingent valuation method (CVM) to analyse the factors affecting shrimp farmers' decisions ($WTA_{Decision}$) on whether to accept a subsidy for VietGAP certificate and a minimum subsidy that farmers are willing to accept ($WTA_{Subsidy}$) for pursuing the VietGAP certificate. It found that $WTA_{Decision}$ had a positive relationship with farmers' education level, environmental perceptions and attitudes toward the VietGAP certificate. Yet those factors had negative effects on the $WTA_{Subsidy}$. In addition, annual income also had a slight effect on farmers' willingness to accept a subsidy value. The findings of this chapter are not only relevant to Tra Vinh province but also to all provinces engaged to shrimp farming or aquaculture in general.

Based on the findings of this study, I can offer some suggestions on how to promote the VietGAP scheme in Tra Vinh province as followings.

The study also states that the current incentive scheme of VietGAP certification in shrimp farming in Tra Vinh province has difficulties that remain. The costs of investment related to construction, facilities and equipment under the VietGAP standard are higher than those of non-VietGAP farming, while direct benefits for farmers such as premium prices were insignificant. Therefore, to inspire shrimp farmers to participate in the VietGAP method, processor enterprises guarantee that the shrimp prices of VietGAP farms are always higher than those of non-VietGAP farms. The production costs under the VietGAP standard are 25% higher compared to non-VietGAP production costs (Marschke et al., 2014). To encourage shrimp farmers to participate in the VietGAP scheme, the authorities should increase the subsidy amount for the investment costs so that it is at least equal to the average subsidy that farmers are willing to accept, which is 20 million VND per 1.000 $m^2$, and keep maintaining other categories of subsidy (Sub1, Sub3, Sub4).

And the 5ha farm size criterion should be dropped to accommodate the majority of small-scale farms in Tra Vinh province. To increase the probability of adoption of the VietGAP standard, the local authorities should launch more information campaigns related to environmental preservation in order to inspire the farmers' commitment to the environment or to improve the farmers' environmental perceptions (*env_perception*). VietGAP guidelines and training courses could help the farmers have a better idea of VietGAP's benefits.

The limitation of this study is that there is no comparison of shrimp productivity between VietGAP farms and non-VietGAP farms. There is also a shortage of specific information on other international certificates (ASC, GlobalGAP, etc.) to compare with VietGAP shrimp farming. However, this study showed the benefits and drawbacks of the application of VietGAP standards and discovered what factors affected the farmers' WTA following VietGAP certification and the WTA amount of subsidy expected for adopting VietGAP certification, which will help authorities and policymakers to make appropriate decisions.

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## Appendix 4.A. Stata do-files

## Cronbach's Alpha test for Environmental perception and Attitude toward VietGAP standard variables

```
. alpha env_per1 env_per2, item

Test scale = mean(unstandardized items)

Average interitem covariance:     .3296767
Number of items in the scale:            2
Scale reliability coefficient:      0.7057

. alpha attitude1 attitude2 attitude3 attitude4, item

Test scale = mean(unstandardized items)

                                                            average
                             item-test     item-rest       interitem
Item         |  Obs  Sign   correlation   correlation     covariance      alpha
-------------+-----------------------------------------------------------------
attitude1    |  300    +       0.7855        0.6267        .3306094      0.7954
attitude2    |  300    +       0.8518        0.7249        .2862022      0.7510
attitude3    |  300    +       0.8010        0.6389        .3151877      0.7896
attitude4    |  300    +       0.8144        0.6353        .2957897      0.7946
-------------+-----------------------------------------------------------------
Test scale   |                                             .3069472      0.8278
-------------------------------------------------------------------------------
```

## Result of regression of $WTA_{Decision}$

```
. logit Decision age education experience farmsize income Env_perception Attitude

Iteration 0:   log likelihood = -165.32398
Iteration 1:   log likelihood = -55.686391
Iteration 2:   log likelihood = -40.672169
Iteration 3:   log likelihood = -38.542775
Iteration 4:   log likelihood = -38.502611
Iteration 5:   log likelihood = -38.502508
Iteration 6:   log likelihood = -38.502508

Logistic regression                               Number of obs     =        300
                                                  LR chi2(7)        =     253.64
                                                  Prob > chi2       =     0.0000
Log likelihood = -38.502508                       Pseudo R2         =     0.7671

--------------------------------------------------------------------------------
      Decision |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
           age |  -.0466643   .0376917    -1.24   0.216    -.1205387      .02721
     education |   .8747267   .4960719     1.76   0.078    -.0975563     1.84701
    experience |   .0600911   .0857378     0.70   0.483    -.1079518    .2281341
      farmsize |  -.0000188   .0000147    -1.28   0.200    -.0000477    9.97e-06
        income |    .007008   .0059312     1.18   0.237     -.004617    .0186329
Env_perception |   2.047122   .5785588     3.54   0.000     .9131671    3.181076
      Attitude |   5.329516    .743111     7.17   0.000     3.873046    6.785987
         _cons |  -26.08084   4.460011    -5.85   0.000     -34.8223   -17.33938
```

## Calculate odds ratio

```
.logit Decision age farmsize education experience income Env_perception Attitude,or

Iteration 0:   log likelihood = -165.32398
Iteration 1:   log likelihood = -55.686391
Iteration 2:   log likelihood = -40.672169
Iteration 3:   log likelihood = -38.542775
Iteration 4:   log likelihood = -38.502611
Iteration 5:   log likelihood = -38.502508
Iteration 6:   log likelihood = -38.502508

Logistic regression                               Number of obs     =        300
                                                  LR chi2(7)        =     253.64
                                                  Prob > chi2       =     0.0000
Log likelihood = -38.502508                       Pseudo R2         =     0.7671

--------------------------------------------------------------------------------
      Decision | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
           age |   .9544077   .0359733    -1.24   0.216     .8864428    1.027584
      farmsize |   .9999812   .0000147    -1.28   0.200     .9999523     1.00001
     education |    2.39822   1.189689     1.76   0.078     .9070512     6.34083
    experience |   1.061933   .0910478     0.70   0.483     .8976709    1.256254
        income |   1.007033   .0059729     1.18   0.237     .9953937    1.018808
Env_perception |   7.745575   4.481271     3.54   0.000     2.492203    24.07265
      Attitude |   206.3382   153.3322     7.17   0.000     48.08862    885.3537
```

```
         _cons |   4.71e-12   2.10e-11    -5.85   0.000     7.53e-16    2.95e-08
--------------------------------------------------------------------------------
```

## Test of correct prediction

```
. estat class

Logistic model for Decision

              -------- True --------
Classified |         D            ~D  |      Total
-----------+--------------------------+-----------
     +     |       224             7  |        231
     -     |         4            65  |         69
-----------+--------------------------+-----------
   Total   |       228            72  |        300

Classified + if predicted Pr(D) >= .5
True D defined as Decision != 0
--------------------------------------------------
Sensitivity                     Pr( +| D)   98.25%
Specificity                     Pr( -|~D)   90.28%
Positive predictive value       Pr( D| +)   96.97%
Negative predictive value       Pr(~D| -)   94.20%
--------------------------------------------------
False + rate for true ~D        Pr( +|~D)    9.72%
False - rate for true D         Pr( -| D)    1.75%
False + rate for classified +   Pr(~D| +)    3.03%
False - rate for classified -   Pr( D| -)    5.80%
--------------------------------------------------
Correctly classified                        96.33%
--------------------------------------------------
```

## Multicollinearity test

```
. qui reg Decision age education experience farmsize income Env_perception
     Attitude, vce(r)

. vif

    Variable |       VIF       1/VIF
-------------+----------------------
    farmsize |      1.57    0.634933
    Attitude |      1.40    0.714805
      income |      1.32    0.756254
   education |      1.15    0.867139
Env_percep~n |      1.13    0.888349
         age |      1.07    0.933605
  experience |      1.05    0.955112
-------------+----------------------
    Mean VIF |      1.24
```

## Result of regression of $WTA_{subsidy}$

```
. reg subsidy age education experience farmsize income Env_perception Attitude if
     Decision==1

      Source |       SS           df       MS      Number of obs   =       228
-------------+----------------------------------   F(7, 220)       =     24.42
       Model |  3594.43061         7  513.490087   Prob > F        =    0.0000
    Residual |  4626.24922       220  21.0284055   R-squared       =    0.4372
-------------+----------------------------------   Adj R-squared   =    0.4193
       Total |  8220.67982       227  36.2144486   Root MSE        =    4.5857

--------------------------------------------------------------------------------
       subsidy |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
           age |   .0010414   .0385625     0.03   0.978    -.0749577    .0770406
     education |  -2.563247   .4354573    -5.89   0.000    -3.421448   -1.705045
    experience |    .150598   .0967515     1.56   0.121    -.0400805    .3412765
      farmsize |   6.16e-06   .0000227     0.27   0.786    -.0000386    .0000509
        income |  -.0308817   .0036447    -8.47   0.000    -.0380647   -.0236986
Env_perception |  -1.343623   .4918464    -2.73   0.007    -2.312957   -.3742897
      Attitude |  -2.569475   .9516422    -2.70   0.007    -4.444977   -.6939735
         _cons |    44.2493   4.739314     9.34   0.000     34.90903    53.58956
```

## Multicollinearity test

```
. vif

    Variable |       VIF       1/VIF  
-------------+----------------------
    farmsize |      1.32    0.759983
      income |      1.30    0.770432
         age |      1.14    0.875325
   education |      1.14    0.880616
    Attitude |      1.08    0.927298
  experience |      1.04    0.959355
Env_percep~n |      1.01    0.990901
-------------+----------------------
    Mean VIF |      1.15
```

## Heteroscedasticity test

```
. hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity 
         Ho: Constant variance
         Variables: fitted values of subsidy

         chi2(1)      =     0.40
         Prob > chi2  =   0.528
```

**Appendix 4.B. Questionnaires**

**Part 1. Socio-economic characteristics**

*At the beginning of the survey, interviewer provides the background information of the VietGAP standard such as its major benefits, the current incentive subsidy for application of VietGAP standard from the government, as well as the estimated average costs of construction, facilities and equipment per hectare under the VietGAP standard.*

*Afterward, ask following questions:*

Q1. Please tell us your name and age.

Name: …………………………… Age: ………………

Q2. Check on respondent's gender.

Male: □ Female: □

Q3. Please let us information about your education degree.

Primary school: □ Secondary school: □ High school: □

College/University: □ None: □

Q4. How long have you experienced shrimp farming?

…………. years

Q5. How is large your farm?

…………. (ha)

Q6. How much is average annual income from shrimp farming?

…………. million VND

**Part 2. Environmental perception**

Q7. It is said that shrimp farming is a main cause of river/canal water pollution. What extent do you agree?

① ② ③ ④ ⑤

On scale from 1 to 5, where 1=Strongly disagree; 2=Disagree; 3=Neither agree nor disagree; 4=Agree; 5=Strongly agree.

Q8. What is water resource like currently?

① ② ③ ④ ⑤

On scale from 1 to 5, where 1= definitely not polluted, 2= slightly polluted, 3= generally polluted, 4= highly polluted, 5= very high polluted.

**Part 3. Attitude toward VietGAP standard**

What extent do you agree with the following questions? On scale from 1 to 5, where 1=Strongly disagree; 2=Disagree; 3=Neither agree nor disagree; 4=Agree; 5=Strongly agree.

Q9. Shrimp's price is higher than the market price if farmer got a certificate of eco-environment (VietGAP).

① ② ③ ④ ⑤

Q10. It is said that shrimp farming under VietGAP standard is beneficial to environment.

① ② ③ ④ ⑤

Q11. The VietGAP standard contributes to sustainable shrimp farming.

① ② ③ ④ ⑤

Q12. A VietGAP certificate in Shrimp farming is the most important in exporting.

① ② ③ ④ ⑤

**Part 4. Willingness to accept a subsidy**

*Interviewer poses a hypothesis that the current subsidy scheme of VietGAP does not care about the criterion of farm size (minimum 5ha). The government would like to support finance to farmers who adopt VietGAP standard in shrimp farming. Afterward ask two following questions:*

Q13: Would you be willing to accept the subsidy scheme for changing from traditional farming system to VietGAP?

□ Yes. (Go to Q14) □ No. (Go to follow-up questions)

Q14. Suppose that total costs of investment of construction and all necessary facilities, equipment under VietGAP standards about 70 million VND per 1,000 $m^2$ of shrimp pond. How much a minimum amount of subsidy would you be willing to accept to do shrimp farming under VietGAP standard?

………… million VND

**Follow-up questions:**

Q15. Why don't you accept the subsidy scheme?

…………………

Q16. What difficulties are you facing if you follow VietGAP standard?

…………………..

Q17. What would you require any more supports from the Government?

…………………