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The Vulnerability of Shrimp Farming Income to Climate Change Events: A Case Study in Ca Mau, Vietnam

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ABSTRACT

Purpose – This paper[4] investigates shrimp income losses of farmers in the four farming systems in the research areas of Ca Mau, Vietnam and determines the vulnerability of shrimp farming income to climate change events.

Design/methodology/approach – Field research interviews were conducted with one hundred randomly selected households across the four farming systems to access shrimp income status and vulnerability levels to climate change events. Four focus groups, each aligned to a particular farming system, were surveyed to categorize likelihood and consequences of climate change effects and based on risk matrix worksheet to derive levels of risk, adaptive capacity, and vulnerability levels.

Findings – Shrimp farmers in the study areas have been facing shrimp income reduction recently and shrimp-farming income is vulnerable to climate change events. There are some differences between farmers' perspectives on vulnerability levels and some linkages evident among shrimp farmer characteristics, ramifications for each farming system, shrimp income losses, and shrimp farmers' perspectives on vulnerability levels of shrimp incomes. From an income perspective, farmers operating in intensive shrimp farming systems appear to be less vulnerable to existing and expected climate change effects relative to those in mixed production or lower density systems.

Originally/value – Having identified the vulnerability level of shrimp farming income to climate change events in different farming systems based on shrimp farmers' perspectives, the paper adds new knowledge to existing research on vulnerability of the aquaculture sector to climate change. The research findings have implications for policy makers to encourage intensive shrimp farming as a strategy for enhancing shrimp farmer resilience to the effects of climate change as well as improving cultivation techniques for shrimp farmers. The findings could guide local government decision-making on climate change responses and residents of Ca Mau as well as within the wider Mekong Delta in developing suitable practical adaption measures.

Key words – climate change event, shrimp farming income, farming system, adaptive capacity, vulnerability

1. Introduction

Ca Mau has the largest area of shrimp farming in Vietnam and adds more than one hundred thousand tons of shrimp production per year in the world market (Ca Mau Statistic Office, 2011). Shrimp production, impressively developed during the last 20 years (Hung, 2011), has become a vital component of the province's economy (SIWRP, 2008) and the major income source for shrimp farmers (Hung, 2011). However, there is an increasing level of local community and political pressure associated with climate change impacts on shrimp production (DARD, 2010). Climate change issues are increasing and exacerbating pressure on shrimp farming production (DONRE, 2011) and directly affecting shrimp income of farmers in the region.

Ca Mau has been recognized as the most vulnerable province in Vietnam to possible damage by climate change (Actionaid & CRES, 2010). Serious adverse effects of climate change events are being experienced by shrimp farmers with a clear evidence that a range of climate change effects are occurring in Ca Mau region of Vietnam (Quach et al., 2015). Shrimp farmers are particularly vulnerable as the number of extreme weather events is increasing in intensity and frequency (Oxfam, 2008). High temperature and irregular weather patterns cause massive losses for shrimp production (NACA, 2011). Based on these bad weather events, shrimp farmers have been adapting to adverse effects of climate change and there is an income cost associated with these measures

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whereby shrimp farmers generate less profit and with evidence that it critically affects their income (RIA2, 2014).

This paper explores shrimp income status of farmers in different farming systems and determines how shrimp-farming income is vulnerable to climate change in terms of farmers' perspectives of the adverse impacts of climate change on shrimp production. Household surveys and focus groups mainly concentrated on shrimp farmers involved in four shrimp production systems: rice-shrimp rotation (RSRF), integrated shrimp-mangrove shrimp (ISMF), separated shrimp-mangrove (SSMF), and intensive shrimp farming (ISF). The research results give a better understanding of shrimp income status of farmers and how shrimp-farming income is vulnerable to climate change events. This can be used to help local governments and inhabitants to gain a better sense of the measures needed for adaptation to climate change in order to sustain shrimp production and its important role in the regional economy.

The following sections review aquaculture and shrimp farming vulnerability to climate change, and then sets out the research methodology. The research results are then explained focusing on shrimp farming income losses and vulnerability to climate change issues based on shrimp householder surveys and focus groups. The discussion section details how shrimp-farming income of farmers in the four farming systems is vulnerable to climate change.

2. Review of aquaculture and shrimp farming vulnerability to climate change events

Based on the definition of climate change vulnerability employed by IPCC (2007), Allison et al. (2009) developed the notion of aquaculture vulnerability and a number of studies since then have focused on this. The vulnerability to climate change of aquaculture in developing countries may also increase (De Silva & Soto, 2009) with Vietnam is indicated as being one of the most vulnerable nations in this regard. Spatial assessment identified climate change vulnerability at the local level within Vietnam (Anh et al., 2012) and a district based climate change vulnerability assessment displayed the spatial distribution of the vulnerability of important sectors (Hung, 2012). The farming sector overall is ranked at a high-risk level and the aquaculture sector is expected to be impacted most heavily in Ca Mau Province (SIWRP, 2008) where it has been recognized as one of the most vulnerable provinces to climate change in Vietnam (Marie-Caroline et al., 2010).

Shrimp farming systems are often associated with coastal areas where vulnerability to climate change impacts is significant (Handisyde et al., 2006). Vulnerability to climate change is intimately linked to poverty (Chaudhry & Ruysschaert, 2007). Local inhabitants in Ca Mau Province are particular at risk and more vulnerable to climate change impacts, which are coming (Oxfam, 2008). Local inhabitants simultaneously are less able to cope with current climate variability, while facing more severe climate events (Huxtable & Yen, 2009) meaning that they are expected to suffer greatly from adverse impacts of climate change in the future (Tuan & Hong, 2012).

Shrimp farmers already perceived the impacts of climate change in coastal areas (Halder et al., 2012). To date most impacts have been identified as extreme climate events, sea level rise, temperature increase, and rainfall change (De Silva & Soto, 2009). These are addressed briefly in turn.

Firstly, the frequency of extreme weather events has increased dramatically over the last five decades (IPCC, 2007) with changing of typhoon patterns, increasing the intensity and frequency hitting Vietnam (MONRE, 2009; Tan, 2010), trending to move to the southern coast of Vietnam (Tan, 2010), and posing a serious threat to Ca Mau Province for both the short term and long term (NEDECO, 2003). For example, Typhoon Linda that struck Ca Mau in 1997 caused loss of life for thousands of people, and destroyed more than 200,000 homes and much of the fishing fleet. Extreme climate events will lead to a reduction in aquaculture productivity and have serious consequences for the economy.

Secondly, sea levels in Vietnam have risen by 20 cm during the period from 1958 to 2007 (MONRE, 2009) and the experience of local inhabitants with this issue has been noted by Actionaid and CRES (2010). Sea levels are expected to rise from 28 to 33 cm by 2050 and 65 to 100 cm by the end of the 21st century (MONRE, 2009). Impacts of this issue could include damage and loss of ponds due to increased coastal erosion and rising sea level, loss of suitable land area, and rising feed costs (Smyle & Cooke, 2011).

Thirdly, the average air temperature in Ca Mau has increased by 1ºC over the last forty years with greatest increase in recent years, a rise of 0.5ºC from 1996 to 2007 (DONRE, 2011). IMHEN (2010) estimated that air temperature will increase up to 0.7°C in 2030, 1.4°C in 2050, and 2.6°C at the end of this century. An increase of the air temperature will result in a corresponding increase in the water temperature (Hammond & Pryce, 2007). Adverse impacts of increased water temperature would become more severe (De Silva & Soto, 2009): exacerbating the occurrence of algal blooms (Najjar et al., 2010), causing toxin release into the water, reducing dissolved oxygen concentrations, spreading pathogens, and threatening fish health and growth (World Fish

Centre, 2009). Shrimp mortality may increase due to high water temperature, increase in disease levels and increased mortality in larvae production systems (Mackay & Russell, 2011).

Finally, the average annual rainfall in Ca Mau has increased by 97 mm during the period of 1972–2007. However, rainfall has shown large fluctuations in the last 15 years; e.g. increased by 45% in 1999 and decreased by 21% in 2004 (DONRE, 2011). Extreme rainfall events in Ca Mau are predicted to increase by 6% in 2030 and 10% in 2050 (IMHEN, 2010) with a trend to decrease rainfall in the dry season and increase in the rainy season (MONRE, 2012). Therefore, the dry seasons will get drier and rainfall in the rainy seasons will be more intense, such as larger volumes in shorter periods. This will exacerbate flooding and drought conditions (Mackay & Russell, 2011) affecting shrimp farmers' production.

Several authors have noted that shrimp farmers are vulnerable to climate change that would lead to a further reduction of profitability, and as a result, higher cost will be required to invest in shrimp farming production (Kam et al., 2012; Smyle & Cooke, 2011, WB, 2010). They claim that sea level rise, high temperature, irregular weather, and too much rain were the most important factors in small-scale shrimp farming. These changes made the greatest impact on small-scale shrimp farming with the losses of 10-30% or even 100% of shrimp farmers' income in improved extensive shrimp farming system- IESF (Hai et al., 2011). Ca Mau shrimp farmers have recognized the adverse effects of climate change on shrimp production in different farming systems (Quach et al., 2015) and acknowledge that serious adverse effects of climate change are occurring. They have ranked more intense or irregular rainfall as having the most impact on RSRF, ISMF, and ISF; while sea level rise was most impact on SSMF. They also agreed that climate change issues have increased shrimp diseases and negatively affected shrimp productivity in the last 10 years (Quach et al., 2015).

From the literature presented previously, it is clear that there is evidence of substantial climate change events being experienced in Ca Mau Province. While there is important literature available that discusses negative impacts of climate change events on farming industry and shrimp production, presently there is little understanding of the vulnerability of shrimp farming to climate change events. The aim of this paper is to understand how shrimp farming in Ca Mau Province is vulnerable to climate change as perceived by farmers, with particular focus on the vulnerability of shrimp farming income to climate change events in the four different farming systems. It is intended that the research be used to help the local government and residents of Ca Mau gain a better understanding of how climate change poses a risk to the farming livelihood of shrimp farmers and what adaptation measures might be put in place reduce these risks and increase resilience to the adverse effects of climate change events.

3. Methodology

3.1. Theoretical concepts

Vulnerability to climate change is a combination of the potential impacts (sensitivity plus exposure) and adaptive capacity (IPCC, 2007). The basic concepts of vulnerability assessment that can be used to develop frameworks for climate change vulnerability, impact and adaptation assessment are well established (e.g. Adger, 1999; Adger et al., 2004; Fussel, 2006, 2007; IPCC, 2007, 2004; Moss et al., 2001; O'Brien & Liechenko, 2000; O'Brien et al., 2004; Turner et al., 2003; Wolf, 2011). Although approaches may vary depending on the specific local context and factors under examination, every assessment needs to consider the key components (Metternicht et al., 2014). Macfadyen and Allison (2009) have clarified definitions of vulnerabilities to apply within aquaculture assessment, and FAO (2013) derived a vulnerability analysis framework for fisheries and aquaculture systems. The World Bank and UNEP developed procedures for economic vulnerability assessment in Vietnam (Oxfam, 2010), followed by the comparative vulnerability risk assessment framework based on the approach generally accepted by IPCC to vulnerability assessment in combination with a risk-based approach for assessing the impacts of climate change and its hazards (ADB, 2011–2013; Mackay & Russell, 2011;). Because of large uncertainties regarding the rate of change, the scale, and the distribution of impacts, the adopted risk assessment approach is based on a "risk matrix" to identify the impacts, adaptive capacity, risk, and vulnerability associated with climate change (Brundell et al., 2011; Mackay & Russell, 2011). The degree of exposure and sensitivity to potential impacts, and the combined effect of potential impact and adaptive capacity gives rise to vulnerability; therefore, levels of vulnerability are assigned from a combination of exposure, sensitivity, and capacity to adapt to the changing climate (Brundell et al., 2011).

3.2. Vulnerability assessment

The process of vulnerability[5] assessment in this paper is based on risk assessment using the impact risk matrix, and the vulnerability matrix approach to determine levels of risk and vulnerability of shrimp farming income to climate change impacts. The impact risk matrix uses the qualitative measures of likelihood and consequence of

[5] The vulnerability of shrimp farming income is a combination of potential impacts and adaptive capacity of shrimp farmers to climate change events on shrimp production based on a risk assessment process. The risk matrix is structured to identify the potential impacts, adaptive capacity and vulnerability to climate change events.

climate change impacts to access the risk levels based on the probability of a particular climate outcome (likelihood) multiplied by its consequences. Likelihood of a climate change impact is classified as "almost certain", "likely", "possible", "unlikely", or "rare"; while consequences are identified as "insignificant", "minor", "moderate", "major", and "catastrophic". These classifications were drawn from the work of Mackay and Russell (2011). Scores and ratings based on qualitative measures of likelihood and consequences are presented in the Table I & II. Levels of risk[6] classified as "extreme", "high", "medium", and "low" derived by combining likelihood and consequence in the impact risk matrix are presented in Table III (Brundell et al., 2011; Mackay & Russell, 2011).

Table I: Livelihood category for climate change impacts

Score	Rating	Recurrent events	Single event
5	Almost certain	Could occur several times/year	More likely than not – Probability (P) grater than 50%.
4	Likely	May arise about once per year	As likely as not – 50/50 change.
3	Possible	May arise once in 10 years	Less likely than not but still appreciable- P less than 50% but quite high.
2	Unlikely	May arise once in 10 – 25 years	Unlikely but not negligible – P low but noticeably greater than zero.
1	Rare	Unlikely during the next 25 years	Negligible – P very small, close to zero.

Table II: Consequence category for climate change impacts

Score	Rating	Profitability and growth (shrimp production)
5	Catastrophic	Shrimp production would be unprofitable, contract markedly, making it unviable. It would need to be wound up.
4	Severe	Shrimp production would be unprofitable, contract markedly, and likely unviable even with significant remedial action.
3	Major	Shrimp production would be unprofitable, contract, and require significant remedial action to remain viable.
2	Moderate	Shrimp production would be only marginally profitable with growth stagnant.
1	Minor	Shrimp production would be profitable, with growth is achieved but fails to meet expectations.

Table III: Risk rating matrix to assess levels of risk by combining likelihood and consequence

Likelihood	Consequences				
	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost certain (5)	M (5)	M (10)	H (15)	E (20)	E (25)
Likely (4)	L (4)	M (8)	H (12)	H (16)	E (20)
Possible (3)	L (3)	M (6)	M (9)	H (12)	H (15)
Rare (2)	L (2)	L (4)	M (6)	M (8)	M (10)
Unlikely (1)	L (1)	L (2)	L (3)	L (4)	M (5)

The vulnerability matrix identifies adaptive capacity to the risks of climate change and determines the level of vulnerability. First, adaptive capacity – the ability of a system to adjust to climate change, to moderate potential changes, to take advantage of opportunities or to cope with negative consequences – is categorized as "low", "medium", or "high" (Brundell et al., 2011). Focus group participants were asked to assign the appropriate category for their farming system on a consensus basis. A low level of adaptive capacity means it is very difficult and costly for shrimp production to implement adaptation activities that are effective. A medium level of adaptive capacity perceives some difficulty and expense in implementing change; however it is possible. A high level of adaptive capacity is where adaptation is feasible and practical. Finally, vulnerability levels are categorized as "low", "medium", and "high", derived from combining impact risk and adaptive capacity (Table IV) assigned by shrimp farmers and utilizing a similar approach as that of Brundell et al. (2011) through the above vulnerability matrix.

Table IV: Vulnerability rating matrix to determine levels of vulnerability by combining levels of risk and adaptive capacity

[6] Risk is understood as a hazard or the chance of a loss. Risk is to be assessed by considering both the consequence of an event occurring and likelihood that the same event occurs. Risk is categorized as follow: **Extreme risk (E ≥ 20)** requires urgent attention to implement adaptation options immediately. **High risk (H = 12-20)** requires attention to develop adaptation options in the near term. **Medium risk (M = 5-12):** expects that existing controls will be sufficient in the short term but will require attention in the medium term and should be maintained under review. **Low risk (L ≤ 5):** requires maintenance under review by control measures but it is expected that existing controls will be sufficient and no further action will be required unless circumstances become more severe.

Impact	Adaptive Capacity		
	Low	Medium	High
Extreme	High	High	Moderate
High	High	Moderate	Moderate
Medium	Moderate	Moderate	Low
Low	Low	Low	Low

3.3. Data collection and analysis

The field study through interview surveys and focus groups was undertaken in Ca Mau Province, Vietnam from November 2012 to February 2013. Four communes were selected for interview surveys and focus groups representing the four shrimp farming systems: RSRF, ISMF, SSMF, and ISF. All shrimp farmers investigated cultivate the same type of shrimp species – the black tiger shrimp.

3.3.1. Interview surveys: Data and information on the status of shrimp income of farmers in the four farming systems was obtained through interviewing shrimp farmers. Farmer household selection was determined through firstly consulting with local key informants to select four communes representing the four types of shrimp farming systems. Second, a list of complying households in the selected communes was made. Third, a target number of households were selected from each commune with from twenty to twenty-five shrimp farmers to be interviewed. Finally, a systematic random selection was used in the surveys (Leedy & Ormrod, 2001). In total 100 shrimp farmers were interviewed, comprising 22 in RSRF, 31 in ISMF, 26 in SSMF, and 21 in ISF. This sample, whilst not necessarily representative of the Ca Mau population of shrimp farmers, is sufficient to provide valuable insight on shrimp farmer perceptions of climate change in the four farming systems. Interviews were conducted with one adult shrimp farmer who responded on behalf of each household, following the approach of Few and Tran (2010). All interviews were semi-structured and interview questionnaires were composed of both open ended and closed questions (Kolb, 2008; Leedy & Ormrod, 2001). Interviewers and participants communicated in Vietnamese during face-to-face interviews (Kvale, 2004; Leedy & Ormrod, 2001). All collected data and information was transcribed into the Excel worksheets and then the qualitative data was summarised, categorised, and grouped according to the techniques of Fielding and Fielding (1986), and Leedy and Ormrod (2001). The quantitative data, such as household characteristics and frequency of respondents, was transcribed into Excel worksheets.

3.3.2. Focus groups: Participants recruited for the surveys were drawn from the sample of interviewees who had been individually interviewed previously (as per Section 3.3.1). The participants involved in the focus groups were senior shrimp farmers who had been living in the communes for a long time and had many years of experience with shrimp production. The selection process was based on that of Morgan and Krueger (1998) and Krueger (2015) with the focus groups comprising between 10 and 20 shrimp farmers for each of the four farming systems. Four focus groups were facilitated comprising 16 participants in RSRF, 21 in ISMF, 14 SSMF, and 16 in ISF. Local key informants helped the lead researcher to invite participants to the target places for the meetings. Face-to-face focus groups were conducted (e.g. Chase & Alvarez, 2000) in Vietnamese. The shrimp farmers did not authorize audio recording, so note taking was during the focus groups (Krueger & King, 1998). The focus group members discussed each climate change impact in turn with the discussions facilitated by the lead researcher. They were asked to individually categorise ratings by using a predetermined scale (e.g. Krueger, 2015) and then to work as a group to arrive at a collective value for each point (as per measures in Tables I & II). This process ensured that every person had an opportunity to speak and share his or her view before arriving at a consensus score for each point examined. In all cases the consensus position was arrived at quite easily, with no sense that particular individuals dominated proceeding or swayed the views of others. Finally, the focus group results and information were collected and analysed (Krueger, 1998) according to risks and vulnerability levels of shrimp farming income to climate change events, based on scores and ratings utilising the matrix worksheets (Mackay & Russell, 2011; Brundell et al., 2011).

A limitation of this research to note is that the interview surveys and the focus groups mostly rely on the opinions and views of shrimp farmers who can be expected to have biases and/or lack of understanding of climate change events. The perspectives of the shrimp farmers are qualitative and may be influenced by other non-climate change related factors.

4. Study sites and shrimp farming systems

4.1. Ca Mau Province overview

Situated on Ca Mau Peninsula, Ca Mau is a flat and low-lying coastal province in the southernmost extent of the Mekong River Delta (SWIRP, 2008). The province occupies 5,392 km^2, making up more than 13% of the Mekong Delta area and equal to 1.6% of the whole country (Actionaid & CRES, 2010). It is surrounded by sea on its two faces and regulated by the tidal regimes of both the West Sea and the East Sea with 245 km of coastline and only 0.75 m of elevation relative to sea level. The climate of Ca Mau is tropical monsoon with two distinct seasons. The area supports more than 1.2 million people with the provincial GDP growth rate around 12% over the past 10 years; the majority of Ca Mau households are engaged in aquaculture (Mackay & Russell, 2011) where shrimp farming dominates the entire sector (Ca Mau Statistics Office, 2011). Shrimp farming is not only a key component of Ca Mau's economy (Mackay & Russell, 2011), but it also represents over 40% of the shrimp farming area of all the coastal provinces in the Mekong Delta (VASEP, 2011). There are two main types of shrimp species (*L. vannamei* and *P. monodon*) cultivated in Ca Mau, but the black tiger shrimp (*Penageus monodon*) is the dominant species farmed across the province (DARD, 2010). Shrimp farming has become the major livelihood and an increasingly important income base for farmers (Hung, 2012). The Ca Mau shrimp area and production characteristics for the last decade are illustrated in Figure 1.

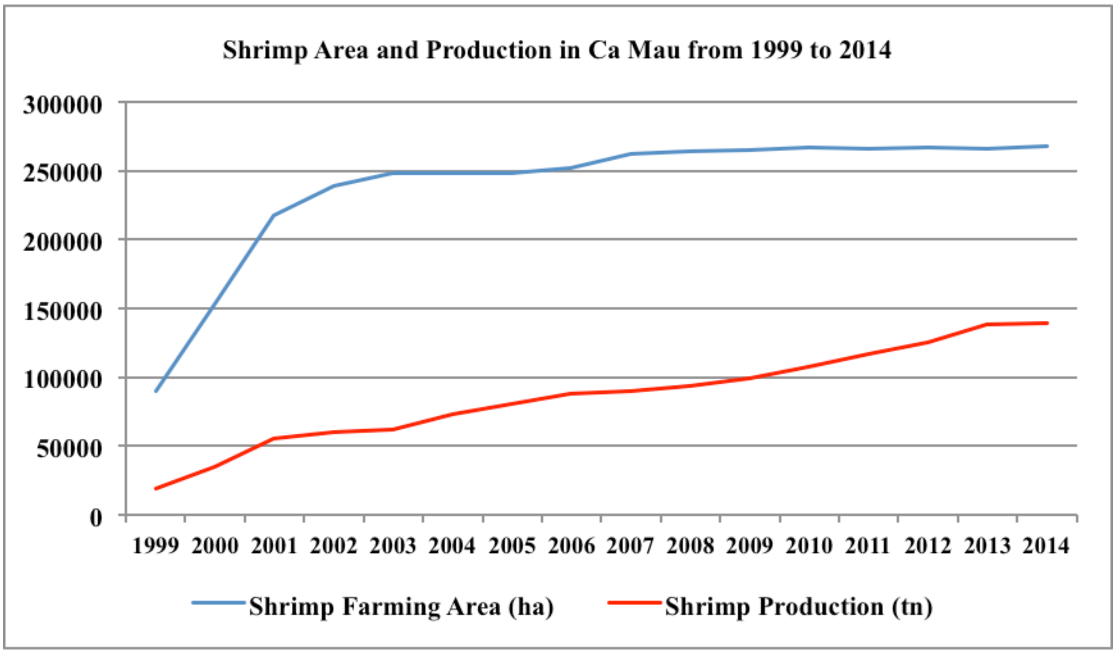

Figure 1: Shrimp farming area (hectare-ha) and shrimp production (ton-tn) in Ca Mau province of Vietnam from 1999 to 2014.

4.2. Shrimp farming systems in Ca Mau Province

Generally, shrimp farming systems in Vietnam are classified as extensive, improved-extensive, semi-intensive, and intensive (Nhuong et al., 2002; Thi, 2007). The Ca Mau shrimp farming categories are based on pond size, method of water exchange, feed and chemical use, and stocking density (Anh et al., 2012), as well as land holding rights, harvest and farming practices (Ha, 2012). Furthermore, in addition to the black tiger shrimp, farmers normally also cultivate crabs or fish and apply extensive, improved-extensive, and/or semi-intensive methods in different systems, such as mangrove-shrimp combinations or rice-shrimp rotation. Thus, combination models and poly-cultivation are popular in Ca Mau. The locations of farming systems targeted in this research are shown in Figure 2 and a brief description of each of the four shrimp farming systems investigated in this research follows.

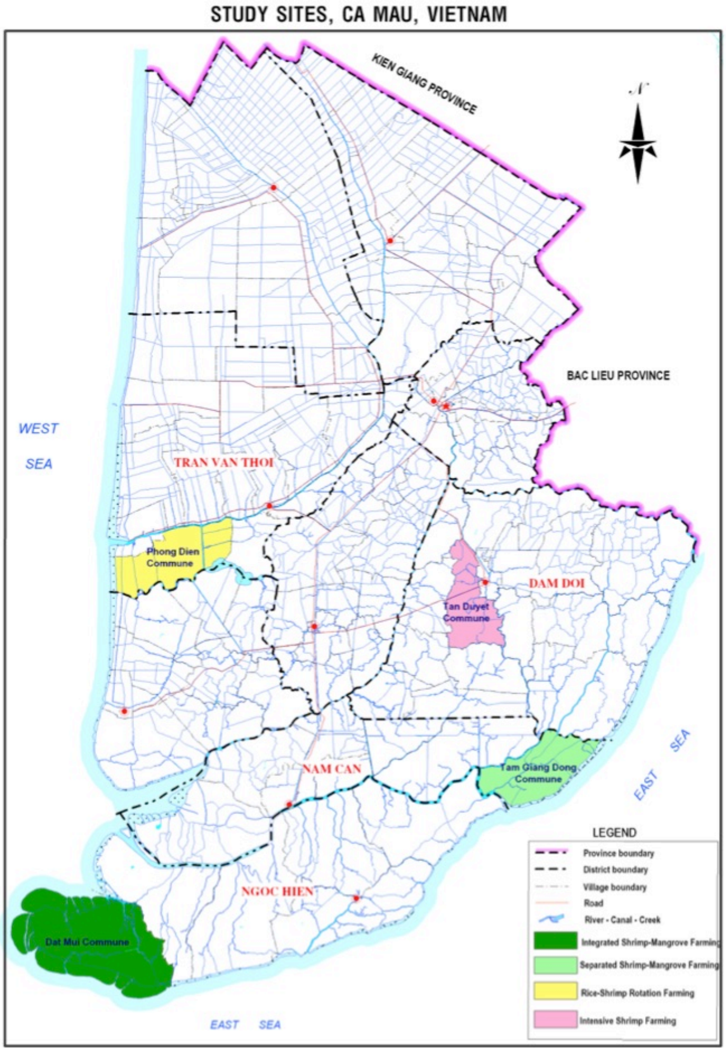

Figure 2: Location of the research study sites

4.2.1. Integrated shrimp-mangrove farming system (ISMF), a traditional extensive farming method with farm size varying from 2 to 17 ha, it relies on wild stock trapped during high tides with no feed supply provided (Minh, 2001; Clough et al., 2002). Legally, the area of mangroves required to be conserved should be 70% of the pond area, but in reality, shrimp farmers typically violate this rule with ditched shrimp pond areas of up to 33–43% of the total pond area (Binh et al., 1997). However, fewer shrimp farmers now practise this model because of natural stock reduction (Graadf & Xuan, 1998). Currently, most shrimp farmers practise ISMF based on artificial stock with a density of 1–3 individuals/m^2 and yielding 300–400 kg/ha/year.

4.2.2. Separated Shrimp-Mangrove Farming (SSMF) is similar to ISMF, but the mangrove area (around 60% of the farm land area) is separated from the shrimp ponds. SSMF in the Tam Giang Dong commune has farm sizes varying from 3.5 to 20 ha. Beside the black tiger shrimp product, both ISMF and SSMF also harvest other products such as wild shrimp species, fish, crab and cockles (Nhuong et al., 2002). Shrimp productivity fluctuates from 333 to 400 kg/ha/year.

4.2.3. Rice-Shrimp Rotation Farming (RSRF) has been practised for many decades in the saline affected areas of the coastal provinces of the Mekong Delta (Vuong, 2011) It is an integrated rice–shrimp system within the same fields with alternative cropping of rice in the wet season and shrimp during the dry season (Brennan et al., 2002). In the dry season, when water salinity is high, saltwater has to be discharged into the fields to farm shrimp. In the rainy season, farmers use rainwater to flush the fields of residual salinity and then grow rice when the water salinity is suitable. Rice fields are designed with a trench, providing a refuge for the shrimps during rice production with a protective dike around the periphery of each field (Brennan et al., 2002). Shrimp productivity of this system is 200–300 kg/ha/year for extensive farming and 250–500 kg/ha/year for improved extensive farming. This model has been expanding and has been considered as a sustainable farming system in recent times (Tran, 1997; Brennan et al., 2002).

4.2.4. *Intensive shrimp farming* started in Khanh Hoa province in central Vietnam in 1989. The pond size for this system varies from 0.2 to 1.0 ha, with a stocking density from 15 to 30 post larvae per m^2, and shrimp productivity of 2,500 to 4,000 kg/crop/ha/year (Nhuong et al., 2002). The farming system reached 3,428 ha in 2011 (DARD, 2011) with pond size from 1,000 to 6,500 m^2, stocking density from 14 to 40 post larvae per m^2, and productivity varying from 3,500 to 6,600 kg/crop/ha in Ca Mau Province (Chinh, 2012).

5. Shrimp farming income losses

The data and information collected from the interview surveys includes household characteristics and status of shrimp farming income and losses.

5.1. Respondent and household characteristics in the four farming systems

A summary of characteristics of the shrimp farmers interviewed in the research and their households is presented in Table V. The average age of interviewees from the four farming systems ranges from 49 to 53 years with the majority being male. The average family size varies from five to six persons per household with the majority of household members achieving secondary schooling. The highest percentage of household members unable to read or write is in SSMS (14%) and RSRF (13%). The majority of family members fell within the normal labor-age (16–60 years) with just over half of all family members engaged in shrimp farming (50–58%) for each of the four farming systems.

Table V: Basic information about respondents and households in the four farming systems

Respondents/ Households	**Age**	**Gender**		**Family size**	**Education of Household Members (Year-%)**					**Labour distribution (%)**	
		M (%)	F (%)		Unable to read/write	1-5	6-9	10-12	Higher Education	Labour Age	Aqua. Labour
RSRF (n=22)	52.8	77.3	22.7	5.6	13.0	6.5	51.2	16.3	14.6	76.4	54.5
ISMF (n=31)	49.6	77.4	22.6	5.3	6.1	12.8	50.0	22.6	8.5	67.1	56.1
SSMF (n=26)	50.6	65.4	34.6	6.1	13.8	10.1	38.4	27.7	10.1	64.2	49.7
ISF (n=21)	52.1	85.7	14.3	5.1	3.7	9.3	45.8	28.0	7.5	71.0	57.9
Total (n=100)	51.1	76	24	5.5	9.4	9.9	46.1	23.7	8.5	69.1	54.2

5.2. Status of shrimp farming income and losses

The characteristics of income sources for shrimp farmers in different farming systems are presented in Figure 3. It was found that farmers in the four shrimp farming systems engaged in different activities to generate income sources, although they were mostly concerned with farming cultivation. The main income–generating activities of shrimp farmers include shrimp farming, poultry and pigs, wages from hired labor, vegetables, aquatic exploitation, and local trading (such as shrimp middlemen, shrimp feeds, nurseries, and hatcheries). The number of activities to generate income for farmers in ISMF is more than those farmers in the other farming systems.

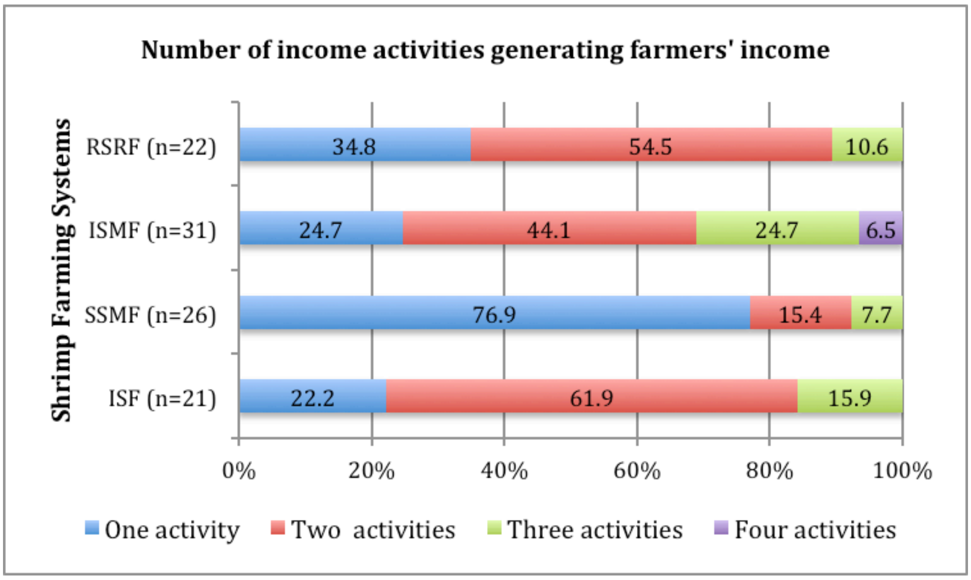

Figure 3. Number of main activities to generate incomes for shrimp farmers in four farming systems

The characteristics of shrimp farming areas and farming income vary considerably between the four farming systems (Table VI). Shrimp farmers in SSMF have larger shrimp area than the others (around twice the area of the others), and farmers in ISF earn the most from shrimp production (on average about twice that of SSMF and ISMF, and nearly five times that of RSRF). The shrimp income per farming area of farmers in ISF is about two and half times that of farmers in ISMF and about four times that of shrimp farmers in RSRF and SSMF, respectively. Irrespective of farming system type, income from shrimp farming is the most important contribution to total income for the farmer families and the proportion is largest (93%) for SSMF; that is, greater by 20–30% than the other three systems.

Table VI: Distribution of shrimp area (ha) and income of households (HH) in the four farming systems

Farming Systems	Shrimp Area (ha)		Shrimp Income (VND M/Ha/Year)		Shrimp Income (VND M/HH/Year)		Household Income (VND M/HH/Year)	
	Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
RSRF (n=22)	1.8	0.8	16.8	12.9	25.3	15.7	40.8	30.6
ISMF (n=31)	2.0	1.1	32.2	17.7	73.3	81.1	73.3	81.1
SSMF (n=26)	3.5	1.5	20.3	12.7	74.4	65.1	80.3	65.1
ISF (n=21)	2.1	1.3	79.8	126.8	154.7	318.1	235.7	424.1

Family income as well as shrimp farming income fluctuates a lot with the biggest fluctuation among shrimp families in ISF. It is evident that the Ca Mau shrimp farmers are facing economic risk based on income characteristics (Figure 4). For example, about one-third of shrimp farmers in ISF (33%) received no shrimp income or paid input values greater than the outputs generated, and only farmers in ISMF were exempt from this lack of shrimp income. As also shown in Figure 4, net shrimp farming income has decreased in all shrimp farming systems in the last three years; again this is especially the case for ISF (77% decrease), compared with SSMF (40%), RSRF (6%), and 9% in ISMF (6%) experiencing the least decreases.

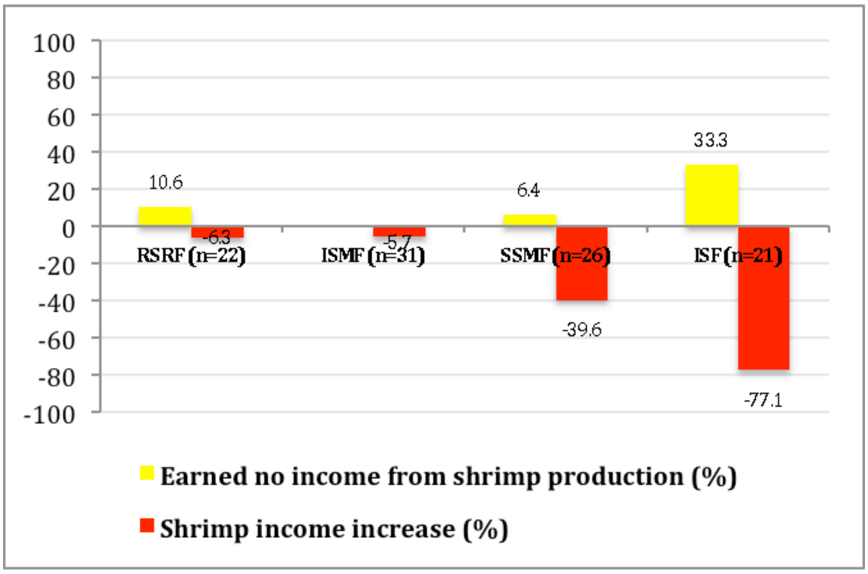

Figure 4: Increase of shrimp income and percentage of farmers who earned no shrimp income from 2010-2012

6. The vulnerability of shrimp farming income to climate change events

The important climate change issues ranked by shrimp farmers that adversely affected shrimp production in the four shrimp farming systems (Quach et al., 2015) were discussed in the focus groups. Participants were asked to categorise the likelihood of occurrence (score: 1 – rare, to 5 – almost certain) and consequence (score: 1 – insignificant, to 5 – catastrophic) to obtain the level of risk of climate change impacts on shrimp income. Levels of risk were derived from multiplying the scores of livelihood and consequence, ranked as extreme risk (E ≥ 20), high risk (H = 12–20), medium risk (M = 5–12), and low risk (L ≤ 5). Results of the risk priority matrix of each climate change impact on farmers' shrimp income in each of the farming systems are presented in Table VII. Overall, all shrimp farmers considered the climate issue of "greater intensity of or irregular rains" as "high risk"; and all other climate change issues as a "medium risk" to shrimp farming income.

Other perceived risk levels of climate change impacts in each shrimp farming system (summarised in Table VIII) are noteworthy. First, shrimp farmers considered "greater intensity of or irregular rains" as "high risk" in RSRF, ISMF and SSMF, but "medium risk" in ISF. Second, seasonal pattern changes were ranked as "high risk" by farmers in RSRF, "medium risk" in ISMF and SSMF, and "low risk" in ISF. Third, increased intensity of high tides was judged "high risk" in SSMF, "medium risk" in RSRF and ISMF, and "low risk" in ISF. Fourth, people in SSMF ranked sea level rise as an "extreme risk" to their shrimp income, a "medium risk" in ISMF; while shrimp farmers in the other farming systems considered this climate issue a "low risk". Fifth, a drier dry season was ranked as a "medium risk" in SSMF and ISF. Sixth, shrimp farmers considered increased fluctuations of water temperature as a "high risk" in ISF, a "medium risk" in RSRF, and a "low risk" in ISMF and SSMF. Finally, only farmers in ISF considered extreme climate events as a "low risk", while farmers in the other systems ranked this as a "medium risk". Overall then, the risk level to shrimp farming income for all climate change impacts is highest in SSMF, then in RSRF and ISMF, while the lowest risk is in ISF.

Table VII: Risk priority matrix of climate change impacts on shrimp farming income ranked by shrimp farmers in the four farming systems

Climate change impact	Farming systems	Consequence	Likelihood	Risk
Greater intensity of or irregular rains	RSRF	4	5	20
	ISMF	3	5	15
	SSMF	4	4	16
	ISF	2	5	10
	Average	3.3	4.8	15.4
Seasonal pattern changes	RSRF	4	4	16
	ISMF	3	3	9
	SSMF	3	3	9
	ISF	2	2	4
	Average	3	3	9
Increased intensity of high tides	RSRF	3	4	12
	ISMF	3	4	12
	SSMF	4	5	20
	ISF	1	2	2
	Average	2.8	3.8	10.3
Sea level rise	RSRF	2	3	6
	ISMF	3	4	12
	SSMF	5	5	25
	ISF	1	1	1
	Average	2.8	3.3	8.9
Drier dry season	RSRF	1	4	4
	ISMF	1	3	1
	SSMF	2	3	6
	ISF	2	5	10
	Average	1.5	3.8	5.6
Increased fluctuations of water temperature	RSRF	2	4	8
	ISMF	1	3	3
	SSMF	1	4	4
	ISF	4	5	20
	Average	2	4	8
Extreme climate events	RSRF	4	3	12
	ISMF	4	2	8
	SSMF	4	2	8
	ISF	3	1	3
	Average	3.8	2.0	7.5

Shrimp farmers in the four farming systems classified levels of adaptive capacity to negative impacts of climate change issues (Table IX). Generally, the levels of adaptive capacity of farmers in ISF and ISMF were perceived to be higher than those of farmers in SSMF and RSRF. This is because they earned a higher family income and had higher levels of shrimp cultivation, as previous results have revealed. More specifically, shrimp farmers in ISF have a high adaptive capacity to the climate change events of increased intensity of high tides, sea level rise, and increased fluctuation of water temperature; while, as might be expected, all shrimp farmers in all systems have a low adaptive capacity to seasonal pattern changes. In ISMF, farmers have low adaptive capacity to seasonal pattern changes and sea level rise, but have a medium adaptive capacity in relation to all other climate change issues. Finally, farmers in SSMF and RSRF recorded a medium adaptive capacity to increased intensity of high tides and increased fluctuation of water temperature, and a low adaptive capacity to the remaining climate change effects on the list.

Table VIII: Summary of risk level of climate change impacts on shrimp farming income.

Climate change events	Levels of risk			
	RSRF	ISMF	SSMF	ISF
Greater intensity of or irregular rains	High (20)	High (15)	High (16)	Medium (10)
Seasonal pattern changes	High (16)	Medium (9)	Medium (9)	Low (4)
Increased intensity of high tides	Medium (12)	Medium (12)	High (20)	Low (2)
Sea level rise	Low (6)	Medium (12)	E (25)	Low (1)
Drier dry season	Low (4)	Low (1)	Medium (6)	Medium (10)
Increased fluctuations of water temperature	Medium (8)	Low (3)	Low (4)	High (20)
Extreme climate events	Medium (12)	Medium (8)	Medium (8)	Low (3)
All climate change impacts	Medium (11.0)	Medium (8.0)	High (12.2)	Medium (6.4)

Table IX: Levels of adaptive capacity to climate change impacts for each shrimp farming system categorised by farmers

Climate change impact	Levels of adaptive capacity			
	RSRF	ISMF	SSMF	ISF
Greater intensity of or irregular rains	Low	Medium	Low	Medium
Seasonal pattern changes	Low	Low	Low	Low
Increased intensity of high tides	Medium	Medium	Medium	High
Sea level rise	Low	Low	Low	High
Drier dry season	Low	Medium	Low	Medium
Increased fluctuations of water temperature	Medium	Medium	Medium	High
Extreme climate events	Low	Medium	Low	Medium

Combining levels of risk and adaptive capacity derived the vulnerability levels of shrimp farming income of farmers in each farming system in relation to climate change impact (Table X). Both RSRF and SSMF show mostly high and moderate levels of shrimp farming income vulnerability to climate change events, with ISMF and ISF fairly evenly split between moderate and low vulnerability levels.

Table X: Vulnerability level of shrimp farming income derived from combining risk level and adaptive capacity

Climate change impact	Levels of Vulnerability			
	RSRF	ISMF	SSMF	ISF
Greater intensity or irregular rains	High	Moderate	High	Moderate
Seasonal pattern changes	High	Moderate	Moderate	Low
Increased intensity of high tides	Moderate	Moderate	Moderate	Low
Sea level rise	Low	Moderate	High	Low
Drier dry season	Low	Low	Moderate	Moderate
Increased fluctuations of water temperature	Moderate	Low	Low	Moderate
Extreme climate events	Moderate	Moderate	Moderate	Low

7. Discussion

The literature review findings and original data collected shows clear evidence of the vulnerability of shrimp farming income to climate change events in the research areas of Ca Mau Province. This is borne out by status of shrimp farming income losses recently and ranking of shrimp farmers in the four shrimp farming systems on shrimp income vulnerability to the negative impacts of climate change issues. However, it is apparent that the perceived vulnerability of shrimp farmers to actual or expected climate change impacts varies considerably according the farming system utilised.

The research results show that shrimp farming is the most important contribution for farmer incomes in the four farming systems, with the majority of shrimp families depending on this income stream to sustain livelihoods. However, shrimp-farming income in all farming systems has decreased in the last few years. Perspectives of shrimp farmers considered that this reduction is likely related to the negative impacts of climate change events (Table XI). The majority of shrimp farmers in the four farming systems recognised the adverse effects of climate change on shrimp production and strongly agreed that those effects have increased shrimp diseases and negatively affected shrimp productivity in the last 10 years (Quach et al., 2015). Previous research conducted on small-scale shrimp farmers in IESF supports this view that the adverse effects of sea level rise, high temperatures, irregular weather, and too much rain have had the most impact on shrimp production with losses of 10–30% or even 100% of shrimp farming income (Hai et al., 2011). Similarly in the present research, it was evident that shrimp farming income is at risk, with evidence of shrimp farmers who received no shrimp income in ISF, RSRF, and SSMF. Chinh (2012) further identifies some problematic issues regarding cultivation techniques in ISF in Ca Mau.

Table XI: Perspective of shrimp farmers in the four farming systems that adverse effects of climate change events on shrimp farming in the research areas in the last 10 years (Quach et al., 2015)

Respondents	Yes		No		Not sure	
	Frequency (F)	Per cent (%)	Frequency (F)	Per cent (%)	Frequency (F)	Per cent (%)
RSRF (n=22)	17	77.3	0	0.0	5	22.7
ISMF (n=31)	29	93.5	0	0.0	2	6.5
SSMF (n=26)	21	80.8	2	7.7	3	11.5
ISF (n=21)	15	71.4	5	23.8	1	4.8
Total (n= 100)	82	82.0	7	7.0	11	11.0

An interesting way to understand the vulnerability of shrimp farming income to climate change in the research areas of Ca Mau in light of the results presented previously is to consider the characteristics and ramifications for each farming system in turn. We do this by combining individual results from Tables V, VI and X, and Figures 3 and 4.

7.1. RSRF shrimp farming income registers as being at high-risk from the greater intensity of or irregular rains and seasonal pattern changes of shrimp farming income that could result in high levels of vulnerability. This is because farmers have low adaptive capacity to these climate change events. The household survey results show that shrimp farmers in this system have the lowest shrimp farming income (VND17M/ha/year) and the smallest shrimp farming area (1.8 ha/household) relative to farmers in the other systems. They also have a comparatively large family size (six persons/household on average) and a high percentage of farmers (13%) who are unable to read and write. While RSRF shrimp farmers have three types of household incomes on average, some 35% of them depend entirely on the shrimp farming income stream.

7.2. *ISMF* shrimp farming income registers as being at high risk from greater intensity of or irregular rains, and medium to low risk from the other climate change events. As a result, shrimp farmers in this system have a moderate to low vulnerability level of shrimp farming income to all climate change events and a medium level of adaptive capacity to most of the climate change impacts. The survey results illustrate that shrimp farmers in ISMF have a higher shrimp farming income (VND32M/ha/year), smaller family size (five persons/household), and a lower percentage of farmers (6%) who are unable to read and write relative to those in the RSRF and SSMF. Moreover, farmers in this system have up to four income streams compared with the rest of the farming systems, which have just three. As the ISMF farms contain mangroves integrated with the shrimp ponds this would presumably provide shelter for shrimp and thereby offer some natural or inbuilt climate change resilience.

7.3. SSMF shrimp farming income registers as being at high risk from greater intensity of or irregular rains and increased intensity of high tides, and extreme risk from sea level rise; all of which point to a high level of vulnerability. Although the survey results show that individual farms are large and contain mangroves separated from shrimp ponds these aspects could be expected to provide some climate change resilience too. Meanwhile, however, shrimp farmers in SSMF have a low adaptive capacity to most of the climate change events. This is because they have a lower shrimp farming income (VND20M/ha/year) compared with those farmers in ISMF and ISF, the biggest family size category (six persons/household), and the highest percentage of farmers (14%) who are unable to read and write compared with the other systems. While there are up to three types of income in SSMF households, the majority of shrimp farmers (77%) have only one income stream and are most dependent overall on shrimp farming income (97%).

7.4. ISF shrimp farming income registers as being at high risk from increased fluctuations of water temperature, but at low risk from most of the remaining climate change impacts. The shrimp farmers in ISF have low to moderate vulnerability level of shrimp farming income to climate change and a high to moderate adaptive capacity to most climate change impacts. The survey results show that these farmers have the highest shrimp farming income (VND80M/ha/year), the smallest family size (five persons/household), and the lowest percentage of farmers (4%) who are unable to read and write compared with the other systems. A large majority of farmers (78%) in ISF have two or three income streams within their households to sustain livelihoods.

Overall, climate change impacts pose a high level of risk to shrimp farming income, which could result in high levels of vulnerability in each of the four farming systems. The risk level of shrimp farming income to each climate change impact found in this research is substantially different among the four farming systems and contrasts with the findings of RIA2 (2014). The level of adaptive capacity to each climate change impact on shrimp production also differs substantially among the four farming systems. Farmers in ISF have higher levels of adaptive capacity than farmers in the other systems for most of the climate change impacts, while shrimp farmers in RSRF and SSMF alike register the lowest levels of adaptive capacity. Overall then, the vulnerability level of shrimp farming incomes in ISF to the effects of climate change would appear to be lower than in the other farming systems. This is because the ISF farmers not only have lower risk levels and a higher adaptive capacity to climate change events compared with the other shrimp farming systems, as explained previously, but their performance characteristics regarding number of income streams, total family income, family size, and education levels are comparatively favourable.

8. Conclusion

Drawing upon the perspectives of shrimp farmers, this research shows that farmers in the research areas with Ca Mau, Vietnam have experienced shrimp income losses in recent years and are vulnerable to climate change events. While there are some differences between farmers' perspectives in the four shrimp farming systems concerning the vulnerability level of shrimp farming income to climate change events, important linkages between the characteristics and ramifications for each farming type and the perspectives of shrimp farmers on the vulnerability of shrimp farming income can be made. Shrimp farmers with a higher level of cultivation (ISF) earned more money than the other farmers and have lower levels of vulnerability; notwithstanding this, they have experienced reductions in shrimp income, which Chinh (2012) links, at least in part, to problems associated with cultivation techniques. In general, the results suggest that from an income perspective, farmers operating in the intensive shrimp farming systems appear to be less vulnerable to existing and expected climate change effects relative to those in the other systems. This finding contrasts with that of Tran (1997) and Brennan et al. (2002) who considered RSRF a sustainable model for shrimp production. This difference no doubt reflects different focus considerations within each study. Nevertheless, it has implications for policy makers who are urged to encourage intensive shrimp farming as a strategy for enhancing shrimp farmer resilience to the effects of climate change, as well as improving cultivation techniques for shrimp farmers. It also points to the value in further research of the relative resilience and vulnerabilities of different shrimp farming systems to climate change. Having identified an understanding of status and vulnerability levels of shrimp income for the different farming systems, it is intended that this information is used to help local government and residents of Ca Mau as well as shrimp farmers within the wider Mekong Delta to gain a better understanding of shrimp income vulnerability to climate change events, which will assist them in developing suitable adaption options.

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