Vulnerability and adaptation to climate change for improved polyculture farming systems in the Mekong Delta, Viet Nam

Case study report

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Executive summary

The shrimp farming case study is conducted in *Cà Mau* and *Bạc Liêu* provinces, Mekong Delta, Southern Vietnam by: (1) organized stakeholder workshops to map farmer's perceptions, adaptation measures and agencies involved; and (2) questionnaire survey to assess vulnerability of the production system to climatic changes and extreme climatic events. Shrimp farming in the Mekong Delta is dominated by small-scale practices in terms of area and production. For example, Cà Mau province contributed about 20% of aquaculture shrimp to the total Mekong Delta and 15% of the nation, especially 91% of the production from the improved extensive model. Yield ranges 133.00 – 159.60kg/ha/season and profit estimated about 8.03 – 17.76 million Dong/ha/season.

Temperature, rainfall, sea level rise, storm and typhoon in the Mekong Delta are predicted to change substantially in the future. For example, sea level may rise about 28 – 33cm by 2050 and about 65 – 100cm by 2100 relative to the baseline period of 1980 – 1999. Local farmers have already observed irregular weather pattern and extreme events for the last decades. There are at least 11 climate change events observed by farmers. The farmers stated that most of climate change impacts have negative impacts (74.75%), 20.56% would have no consequence and 4.69% have positive impacts. Opportunity to diversify likelihoods into multi-cropping (rice crop in the wet season and shrimp in the dry season) is a typical positive impact from salt intrusion.

Farmer perceptions of climate change are identified: High temperature, Water level rise, Rainfall in the dry season, Storm and typhoon, and irregular seasonal change. Farmers stated that “High temperature” is the most important factors influencing their shrimp farming followed by “Storm and typhoon”, “Sea level rise”, and “Rainfall”. Meanwhile, group of Science and Technology claimed that “Rainfall” is the most important due to irregular and unusual weather, followed by “Storm and typhoon”, “High temperature”, and “Sea level rise”.

Adaptation measures are identified by farmers and have been adapted to climate change. For “High temperature”: change surface water, make pond deeper, increase dike height, make ditch wider; For “Storms & typhoons”: improved pond dike (wider and stronger), use probiotic to improve water quality, improve sluice gate; For “Sea level rise”: improved pond dike (wider and stronger), improve forecast information/ monitoring, use net to prevent shrimp escape, use water pumping machine; For “Rainfall”: use lime to adjust water quality, change water surface, use aerator.

Policy frameworks including the policy options are also recommended by Science and Technology Group, including applying Best Management Practices or aquaculture certifications, new pond design, seed quality control, accurate weather forecast, planting mangrove for coastal erosion protection, crop calendar management, planning and zoning for rice and shrimp culture, salinity tolerance species.

Actions plan to respond to climate change should undertake: (1) Training of farmers and trainers by regular training, posters, workshops, education, mass media and materials on policy/strategy; (2) More funding for improving infrastructure (dike and sluice gate maintenance) (24.3%) by establishing credit programmes and allocating a reasonable budget for related activities; (3) Need for standard routines for monitoring shrimp farms to monitor water/seed quality and inspect disease outbreaks and then inform/advise farmers in order for farmers; (4) Establishing shrimp cooperatives/clubs as co-management models to solve conflicts between farmers in water and management and disease infection; (5) Plan and zone for aquaculture at sustainable development by GIS tools and analysis; (6) Establish new farming models and improve pond design by intensify the farming system in a small area as a nursery area or intensive farming area; (7) Diversify livelihoods to improve farmers’ income and resilience capacity to climate change; (8) Enhance shrimp population in the wild by regularly release into the wild; (9) Good Aquaculture Practices should be encouraged for farmer communities; (10) Establish “New rural development model” as recently approved by the Central Government with the aim at supporting a group of local people in shrimp farming to improve household’s income and sustainable development.

Acknowledgement

Research Institute for Aquaculture 2 (RIA2) would like to thank the Norwegian Agency for International Development (NORAD) and Network of Aquaculture Centres in Asia-Pacific (NACA) for support the Aqua Climate project. We also thank the Project partners: Akvaplan-niva ÅS, Bioforsk and Kasetsart University for your contributions to the case study of shrimp in the Mekong Delta.

Abbreviation

AAPF	Applied Aquaculture Production Function
APRCC	Action Plans to Respond to Climate Change
CCI	Climate Change Impact
FCR	Feed Conversion Ratio
IPCC	Inter-governmental Panel on Climate Change
MARD	Ministry of Agricultural and Rural Development
MIC	Ministry of Information and Communication
MND	Ministry of National Defense
MOC	Ministry of Construction
MOCS	Major Operating Cost Structure
MOCST	Ministry of Culture, Sport and Tourism
MOD	Ministry of Defense
MOET	Ministry of Education and Training
MOF	Minister of Finance
MOF	Ministry of Transportation
MOFA	Minister of Foreign Affairs
MOH	Ministry of Health
MOHA	Ministry of Home Affairs
MOIT	Ministry of Industry and Trade
MOLISA	Ministry of Labour, Invalids and Social Affairs
MONRE	Ministry of Natural Resources and Environment
MOST	Ministry of Science and Technology
MPI	Minister of Planning and Investment
MPS	Ministry of Public Security
NCCS	National Climate Change Strategy
NTP-RCC	National Target Program to Respond to Climate Change
PA	Physical Aspects
PIA	Production Input Aspects
PMA	Production Management Aspects
SP-RCC	Support Program to Respond to Climate Change

Chapter 1 – Introduction

1.1. Aquaclimate project

The Aquaclimate project is in line with the advocacy to strengthen the adaptive capacities of rural farming communities to the impacts of climate change. This three-year project focuses on small-scale aquaculture and related sectors in the south and south-eastern Asian region that are comprised largely of poor people who depend on aquatic resources for their livelihoods. The project assessed the impacts of climate change on small scale aquaculture sector (environmental, socio-economic and institutional) in five selected study areas in four countries comprising Vietnam, Philippines, India and Sri Lanka.

The project maped farmers' perceptions and attitudes towards prospective climate change impacts and their adaptive capacities to address these impacts. The project developed future scenarios based on the current trends, assess the potential adaptive measures for different aquatic farming systems and prioritized better practices, suggested Codes of Practices and improved methodologies for such systems.

The project provided small-scale farmers with strategies to maintain their resilience in the face of climatic change. The project aimed to establish guidelines, frameworks and tools for policy and action programs of governments, development assistance agencies, non-government organizations, and farming communities that would increase the resilience and enhance adaptive capacities of resource-poor, small-scale aquaculture farmers and those dependent on aquatic resource for livelihoods to the impacts of climatic change. It provided information for investments in research, technology development and transfer, public education, training, infrastructure and systems, markets, financial and other support services for the poor farmers and aquatic resource users.

Climate change will affect farming systems worldwide. It is expected that the impacts will be disproportionately felt by small-scale farmers who are already amongst the most poor and vulnerable members of society. Ecological changes, inundation of low-lying lands and saline intrusions into freshwater regions are likely to cause substantial dislocation of communities and disruption of farming systems. There is a need to forecast the likely effects of climate change on the aquaculture sector and to develop strategies to assist farmers and rural communities to adapt to the coming changes.

The project was implemented via five work packages, as follows:

1) Assessment of impacts of climate change on small-scale aquatic farming systems and the potential contribution of these systems to greenhouse gas emissions.
2) Risk perceptions, attitudes and risk management behavior, status of resiliency, adaptive capacities and adaptation strategies of small-scale farmers.
3) Developing adaptive solutions and scenario-building of the changes on the resources and livelihoods options of poor and small aquaculture households, and the risks and opportunities presented by climate change.
4) Policy and analysis and adaptation strategy development.
5) Project coordination, results dissemination and follow up action.

The project is implemented by international and national partners, with each international partner bringing different areas of expertise and having different areas of responsibility within the project. The coordinating organization of the Aquaclimate project is the Network of Aquaculture Centers in Asia-Pacific (NACA) – Bangkok, Thailand. In addition, there are three international project partners: (1) Bioforsk – The Norwegian Institute for Agricultural and Environmental Research, Ãs, Norway; (2) Kasetsart University, Coastal Development Centre & Aquaculture Business Research Centre of Fisheries Environmental Science Department, Thailand; and (3) Akvaplan-niva ÃS, Tromso, Norway.

1.2. Case studies in the Aquaclimate project

There were 5 case studies varying in geographical location, culture system and species as follows:

1.2.1. Tiger shrimp pond farms in *Cà Mau* and *Bạc Liêu* provinces, Vietnam.

Extensive Shrimp farming on the Mekong Delta in Vietnam is an important source of income and livelihood for many small scale farmers. This sector has been influenced by international market trends, fluctuating prices, diseases outbreaks and last but not the least climate variability in the recent years. The Mekong Delta has had a number of extreme climatic events in the past few years and is also subject to increasing saline water intrusion, for which there are already government operated barriers to regulate the saline water intrusion in some canals.

Shrimp farming in the lower Mekong Delta is practices in with a number of different production systems ranging from large scale intensive, semi-intensive and extensive. The extensive or "improved extensive" where some modifications/improvements have been made to the pond system, is the largest production system type by area and production and is largely characterised by small-scale farmers with <3ha in farm area per farmer/family.

Improved extensive shrimp farmers practice a number of different systems including reliance on naturally occurring shrimp (*Penaeus merguiensis*, *P. indicus and Metapenaeus ensis*) post larvae or juveniles in the influent water, while others are stocking with hatchery reared tiger shrimp (*P. monodon*).

The study focus on farmers raising *P. monodon* under improved extensive farming conditions. Farmers undertaking improved extensive farming also typically undertake polyculture of tiger shrimp with mud crab. Furthermore within the improved extensive tiger shrimp farming sector there are two broadly different systems, ie. with or without rice farming depending on salinity conditions. Farms with low salinity during the wet season culture rice during the low salinity period. Farms with high salinity throughout the year practice shrimp culture without rice culture.

The case study partner was Research Institute for Aquaculture 2 (RIA2).

1.2.2. Pangassius catfish pond farms in the provinces of *Cần Thơ, An Giang, Vĩnh Long, Đồng Tháp* – Vietnam.

The Mekong Delta is the "food basket" of Vietnam, and is of significance both from a production (volume and economic) and livelihood viewpoints. Vietnam is prone to extreme weather events. Cyclones regularly impact Vietnam raising sea levels and sending saline storm surges up estuaries. Flooding is also a common occurrence. Vietnam, particularly the Mekong delta is highly vulnerable to climate change especially extreme weather events. Catfish farming on the Mekong Delta is one of the world's fastest growing aquaculture sectors and is Vietnam's largest aquaculture sector by both volume and value. Catfish (*Pangasianodon hypophthalmus*) is a freshwater fish native to the Mekong river system (including Vietnam) that is cultured almost entirely in deep earthen ponds at very high density. The catfish farming industry and associated industries contributes significantly to the livelihoods of the local population.

The case study partner was the College of Aquaculture and Fisheries, Cần Thơ University (CTU).

1.2.3. Tiger shrimp pond farms in India.

Tiger shrimp (*Penaeus monodon*) has been the mainstay of India's seafood exports and has immense potential as a foreign exchange earner. It also has substantial contribution towards socio-economic development in terms of income and employment. Shrimp aquaculture is threatened by changes in temperature, precipitation, drought and storms/floods that affect infrastructure and livelihoods which can impact aquaculture both negatively and positively. Ecological changes, inundation of low-lying lands and saline intrusions into freshwater regions are likely to cause substantial dislocation of communities and disruption of farming systems.

In the face of potential complexities of climate change interactions and their possible scale of impact, the primary challenge for the shrimp aquaculture sector will be to deliver food supply, strengthen economic output and maintain and enhance food security. It is expected that the climate change impacts will be disproportionately felt by small-scale shrimp farmers who are already amongst the most poor and vulnerable members of society. The small scale farmers are typically unorganised and most farmers do not have access to technological innovations and scientific applications. There is a need to forecast the likely effects of climate change on the shrimp aquaculture sector and to develop strategies to assist farmers and rural communities to adapt to the upcoming changes.

It is estimated that the country has 1.2 million hectares (ha) of brackish water area and 5.4 million ha of freshwater sites for development of shrimp and fish farming respectively. Andhra Pradesh contributes more than half of India’s shrimp production and the state has been at the forefront of the industry since the beginning.

Although the state does not have ideal tidal amplitude conditions for shrimp farming the industry can be expanded through the excavation of ponds to depths that would allow tidal water exchange or to avoid excavation by putting a dyke around and use pumps for filling and water exchange. Both processes introduce heavy cost elements and technical uncertainties, risking both the technical and economic viability. The water quality in respect of year-round salinity distribution, chemical and physical nature of soil, and availability of seed in the state are favourable for coastal shrimp aquaculture. The availability of vast tracts of saline land coupled with abundant wild seeds and strong export demand for shrimp were initially responsible for attracting the entrepreneurs towards shrimp farming.

Andhra Pradesh has had many weather related impacts in recent years such as the worst drought in half a century, which occurred in early to mid-2009, followed by a severe flood of once in 100 years in October 2009 to name a few. These extreme climatic events have had severe consequences including heavy economic losses to shrimp farmers in the state.

The case study partners are the Central Institute of Brackish water Aquaculture (CIBA) and the National Centre for Sustainable Aquaculture (NaCSA).

1.2.4. Culture based fisheries in selected reservoirs in Anuradhapura, Kurinegala, Hambantota, Moneragala, Ratnapura and Puttalam districts in Sri Lanka.

Culture based fisheries (CBF) that are practiced in Sri Lanka and throughout the Asian region are becoming more popular. CBF are a secondary and a non-consumptive user of existing water recourses and do not compete with the traditional rice paddy or land or water and thus can be an additional low resource requirement activity with direct benefits to rural communities. The activity which is principally and typically conducted in non-perennial small water bodies are primarily dependent (for stocking, growth period and harvesting) on the rainfall patterns.

In the recent decades, the rainfall patterns have undergone changes and as a result, water scarcity and excess water have become a recurrent problem in crop production in Sri Lanka. CBF can be impacted by the timing of water availability as seed stock production must coincide when the water is available for stocking and in the case of reduced duration of water availability this impacts on the ability of the fish to reach market size.

The case study was based on hydrological modeling of water resources in reservoirs in combination with fishery information and is heavily reliant on secondary weather, reservoir and catchments data.

The case study partner was Kelaniya University.

1.2.5. Milkfish pond farms in the municipalities of *Dumangas* and *Barotek Nueva*, Philippines.

The Philippines an Archipelago of islands has been identified as being highly vulnerable to climate change such as to increased frequency and intensity of heat-waves, floods, droughts, typhoons. Furthermore, it has been identified that the populous are at particularly high risk as they live in naturally hazard prone areas and are dependent of natural resources for their livelihoods (Rincón & Virtucio 2008).

Milkfish brackish water pond farmers in the Philippines generally operate at the extreme coastal fringe, are reliant on the natural resources (primarily for water but also for wild fish fry) and the majority operate largely ecosystem based aquaculture (largely reliant on primary production in ponds as a food source for milkfish) which is greatly influenced by the natural weather conditions. The milkfish pond farming industry in the Philippines and specifically in Iloilo is also quite significant in terms of production volume and value, contributing to the rural livelihoods. These factors make the present case study particularly significant.

Milkfish production in 2008 was 69 MT. The milkfish industry however is facing challenges such as reduction in area of production by 4,982 hectares, high cost of inputs, climatic changes such as sea level rise and outbreaks of calamities making the production areas vulnerable to destruction and stock loss. (Attachment 19 is the detailed input on the milkfish situation in Iloilo).

Major climate changes include higher water temperature, floods, increased in frequency and intensity of typhoons, drought and sea level rise. Impacts on aquaculture include reduce availability and period of change of wild seed stock, loss of land, lesser availability of ground water and destruction of facilities. Increase in temperature is observed to increase disease transmission, deplete oxygen, increase incidence of harmful algal blooms to mention a few.

The case study partner was Bureau of Fisheries and Aquatic Resources (BFAR).

1.3. Shrimp production in the Mekong Delta

Mekong Delta of Vietnam has a total area of 4.05 million hectares (accounting for 12.2% of the total Vietnam territory) and 17.27 millions of people (accounting for 19.87% of the Vietnam population). There are 13 provinces in the Mekong Delta: 5 inland provinces (*An Giang, Đồng Tháp, Cần Thơ, Vĩnh Long, Hậu Giang*) and 8 coastal provinces (*Kiên Giang, Cà Mau, Bạc Liêu, Sóc Trăng, Trà Vinh, Bến Tre, Tiền Giang*, *Long An*) (Figure 1).

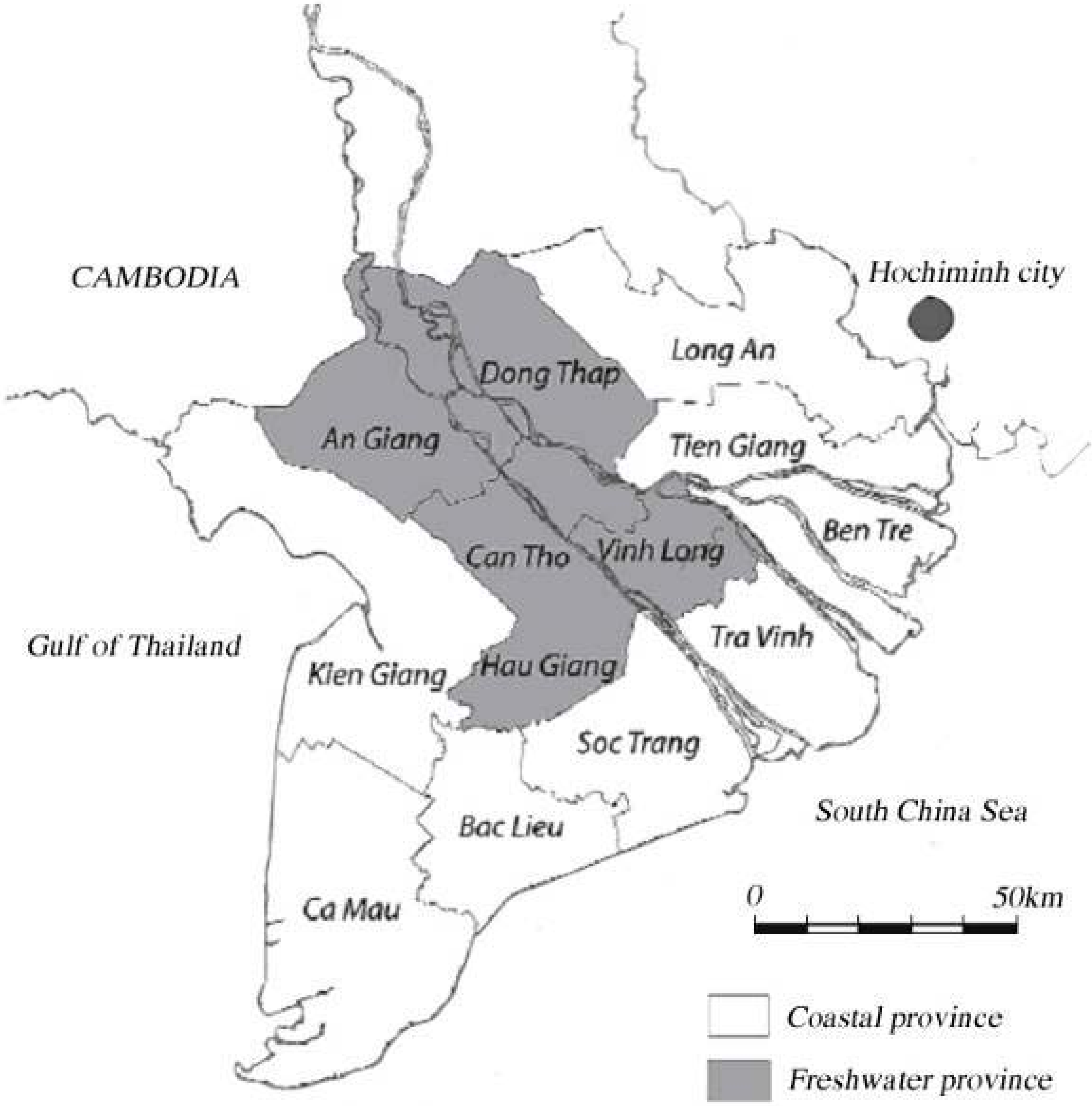

Figure 1: Administration map of the Mekong Delta

Mekong Delta is considered as "food basket" of Vietnam. Based on official statistics in 2010, production from the Mekong Delta contributed a substantial portion to the national production in different sectors, particularly in aquaculture and capture fisheries (Figure 2). For example, shrimp production of the Mekong Delta accounted for 75.74% of national shrimp production; aquaculture fish production (73.35%); rice production (53.94%); and capture production (41.07%).

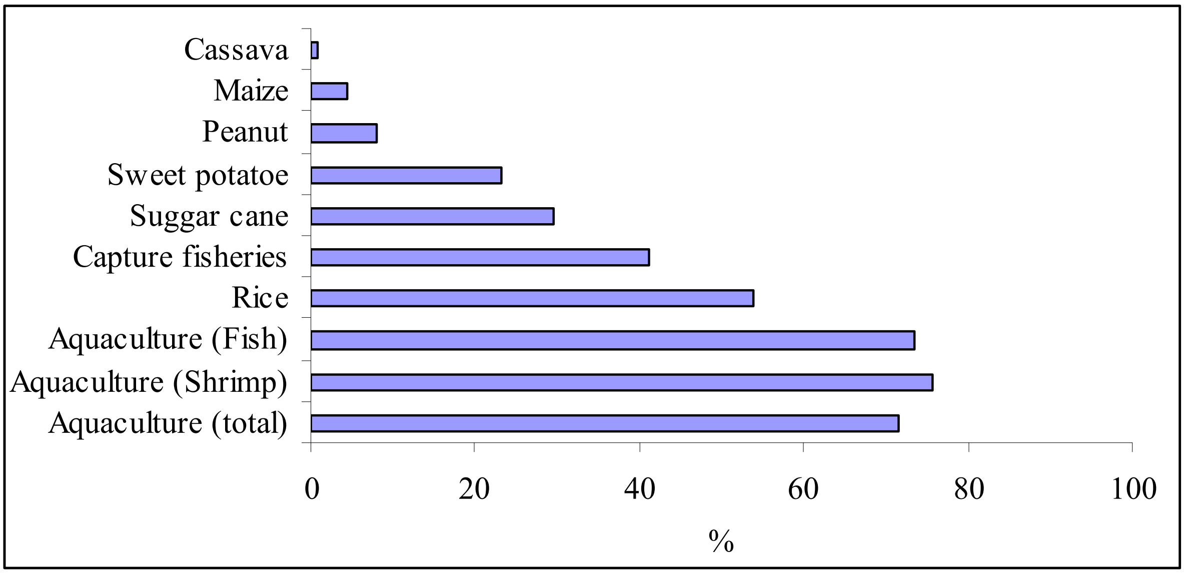

Figure 2: Percentage of production in the Mekong Delta contributing to the national production in different sectors in 2010

There is a steady increase in area of water surface for aquaculture in the Mekong Delta from 289,400ha (1995) to 753,300ha (2010). Considerably, the substantial increase in area for aquaculture (from 1999) is mainly because that farmers in *Cà Mau* and *Bạc Liêu* provinces changed their farming system from rice to shrimp farming. Meanwhile area of water surface in other provinces slightly increases (Figure 3).

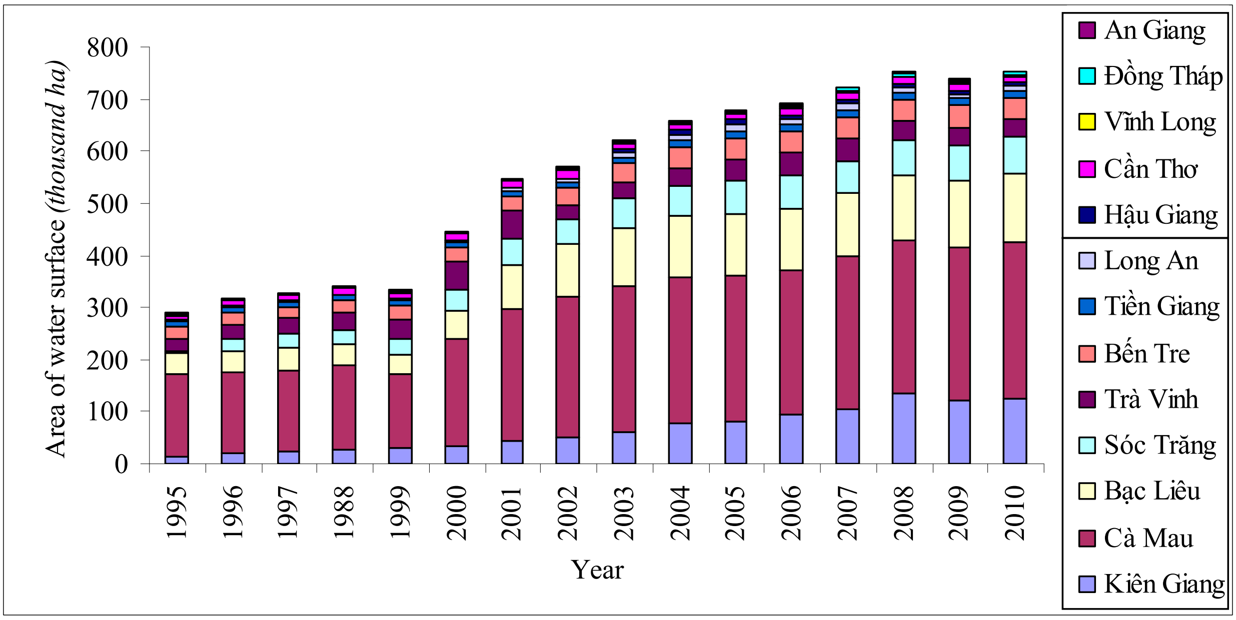

Figure 3: Area of water surface for aquaculture in the Mekong Delta

Shrimp farming in the Mekong Delta just concentrates in the coastal provinces (see Figure 1). Black tiger shrimp (*Penaeus monodon*) and white leg shrimp (*Litopenaeus vannamei*) are the key species in the Mekong Delta. Shrimp farming in the Mekong Delta is practices in with a number of different production systems ranging from large scale intensive, semi-intensive and extensive. Generally, there are five types of farming model based on mainly stoking density and pond area as follows: extensive model, improve extensive model, semi-intensive model, intensive model, and supper-intensive model. The extensive and "improved extensive" where some modifications and improvements have been made to the pond system, is the largest production system type by area and production and is largely characterized by small-scale farmers Table 1.

Table 1: Characteristics of shrimp farming systems in the Mekong Delta

Category	Shrimp farming model		
	Extensive	Improve extensive	semi-intensive and extensive
Area (ha)	3 – 5	1 – 3	1 – 4
Water surface area	30 – 50%	60 – 70%	70 – 75%
Source of seed	Mainly from natural + partly supplemented seed from hatcheries	Mainly from natural + partly supplemented seed from hatcheries	Seed from hatcheries
Density *(indi/m^2)*	5 – 7 (1 crop/year) 1 – 1.5 (2 crop/year)	6 – 7 (1 crop/year) 1 – 2 (2 crop/year)	15 – 45
Crop calendar	Jan-May (crop 1) Jun-Nov (crop 2) All year round	Jan-May (crop 1) Jun-Nov (crop 2)	Jan-May (crop 1) Jun-Oct (crop 2)
Feed provided	No	Supplemented artificial food or man made	100% artificial food
Chemicals + Biotic	No	Partly yes	Yes
Survival rate	17 – 18% (1 crop/year) 24 – 25% (2 crop/year)	18 – 20% (1 crop/year) 3 –5% (2 crop/year)	39% (crop 1) 27% (crop 1)
Productivity *(kg/ha/year)*	285	195 (per crop)	1 – 3 tons for semi-intensive; 5 – 7 tons for extensive
Total costs *(million Đ/ha/year)*	7.7	5.4	100 – 150 (per crop)
Total income *(million Đ/ha/year)*	9.5	11.3	250 – 300 (per crop)
Profit *(million Đ/ha/year)*	1.8	5.9	150

Source: Data from College of Fisheries and Aquaculture – Can Tho University (2003)

Extensive and improved – extensive models are popular in mangrove forest areas. In the past, extensive model was the most popular in the Mekong Delta (68% extensive; 27% improved – extensive; 5% intensive) (Nguyen Thanh Phuong, Truong Hoang Minh, Nguyen Anh Tuan, 2004). However, extensive model is relied on seed from the wild that declining significant in recent years. Therefore, local farmers tend to change to improved – extensive model.

Extensive – Improve extensive Intensive

Figure 4: Shrimp farming system in coastal of the Mekong Delta

There is a sharp increase in shrimp production in recent years (Figure 5), especially in *CàMau* (30.46%), *Bạc Liêu* (19.94%), *Sóc Trăng* (17.83%), *Kiên Giang* (10.19%), *Bến Tre* (8.94%), *Trà Vinh* (6.14), other provinces with only 1 – 4%.

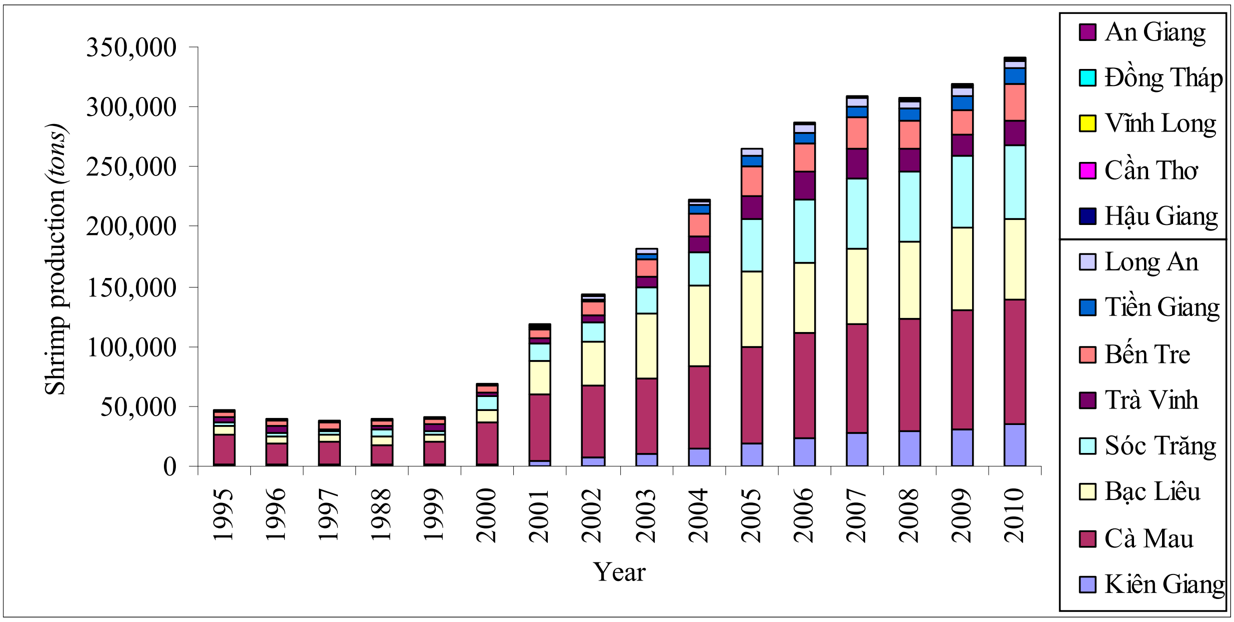

Figure 5: Shrimp aquaculture production in the Mekong Delta

1.4. Shrimp production in Cà Mau and Bạc Liêu province

Mekong Delta has an area of 4.05 millions ha (12.24% of the Vietnam territory) with 17.27 millions of people (19.87% of the total population) and divided into 13 provinces: 7 inland and 8 coastal provinces. *Cà Mau* and *Bạc Liêu* are located in the *Cà Mau* peninsula (Figure 6) and have an area of 533,200ha and 250,200ha respectively. Areas of the two provinces accounted for 19.3% of the total areas of the Mekong Delta.

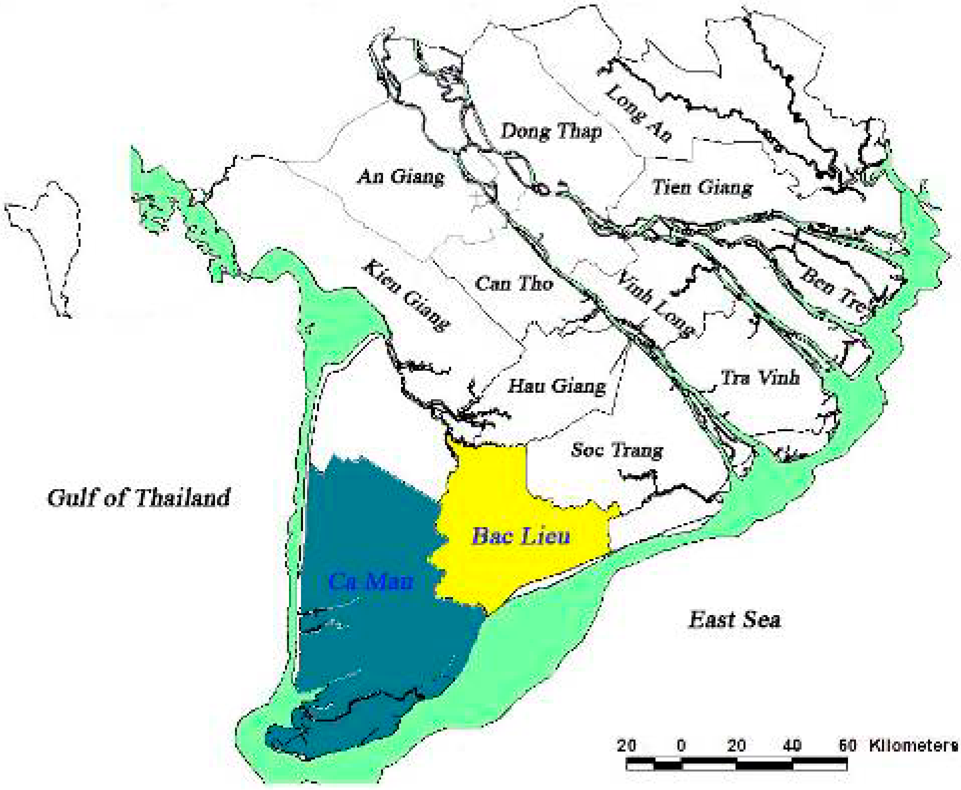

Figure 6: Map of the Mekong Delta

Cà Mau and *Bạc Liêu* provinces are potential for aquaculture development, especially for shrimp as located in coastal areas. In *Cà Mau* province, there are a total of 294,659 ha for aquaculture (55.26% of the province). In which, there are 89.99% for shrimp. Meanwhile, there are 126,338 ha for aquaculture development in *Bạc Liêu* province (50.49% of the province). In which, there are 68.32% for shrimp culture (Table 2).

Table 2: Area of water surface for the aquaculture in *Cà Mau* and *Bạc Liêu* 2009

Category	**Cà Mau**		**Bạc Liêu**	
	Ha	**%**	**Ha**	**%**
1. Marine/Brackish Shrimps	265,153	89.99	86,313	68.32
2. Marine/Brackish Fishes	1,388	0.47	451	0.36
3. Others (Marine/Brackish)	380	0.13	37,875	29.98
4. Freshwater Fishes	27,728	9.41	1,689	1.34
5. Area for Breeding	10	0.00	10	0.01
Total	***294,659***	***100.00***	***126,338***	***100.00***

(Statistical year book of Cà Mau and Bạc Liêu, 2010)

There is a remarkable increase in aquaculture production. Total aquaculture production in *Cà Mau* increased from 46,969 tons (1995) to 235,550 tons (2010) and contributed to 12.14% of the Mekong Delta and 8.70% of the nation. *Cà Mau* is the third largest aquaculture production province in the Mekong Delta (after *Đồng Tháp* and *An Giang* provinces). Similarly in *Bạc Liêu*, total aquaculture production increased from 8,503 tons (1995) to 143,725 tons (2010) and contributed to 7.41% of the Mekong Delta and 5.31% of the nation. This is the sixth largest aquaculture production province in the Mekong Delta (Figure 7).

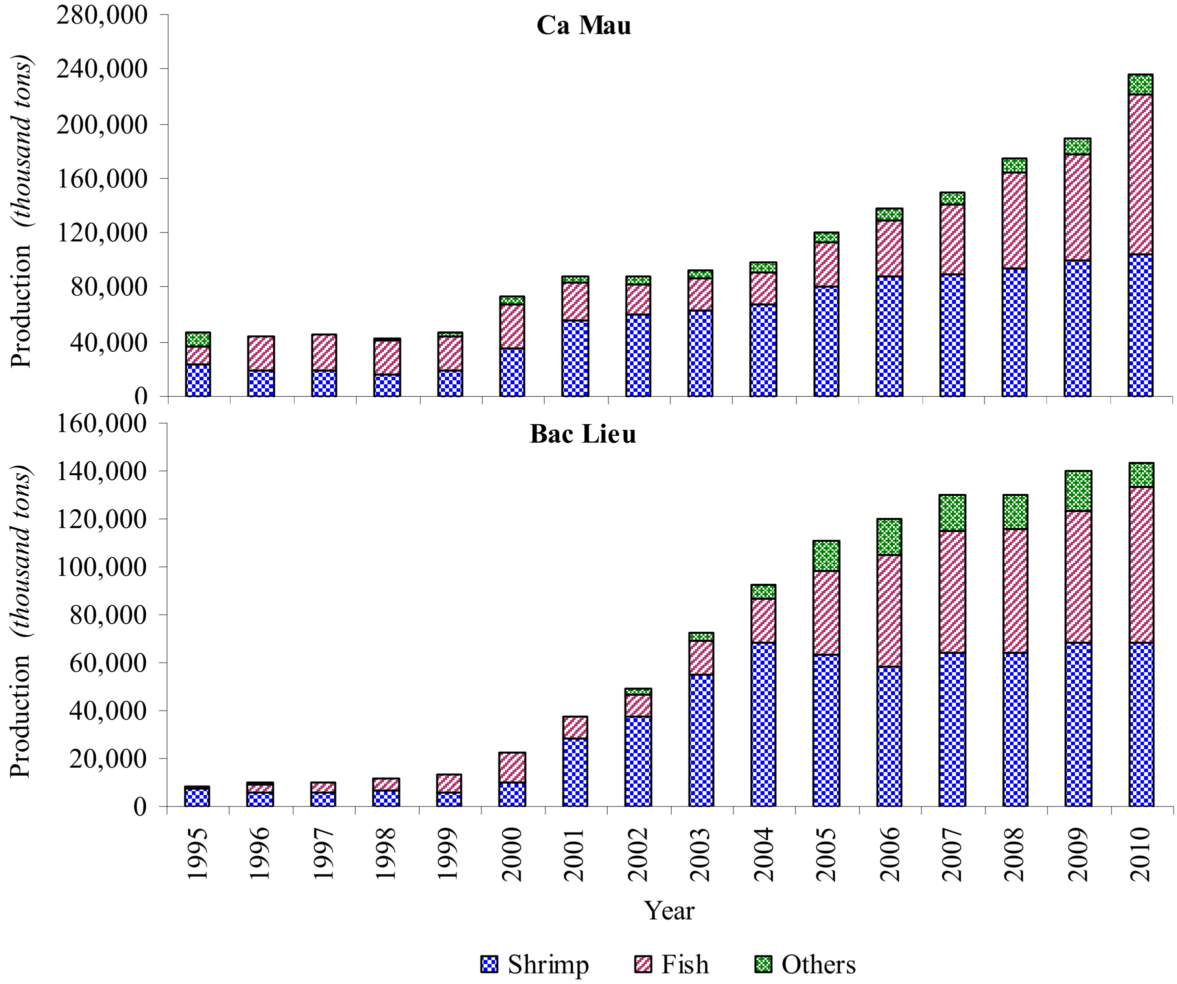

Figure 7: Production of aquaculture in *Cà Mau* and *Bạc Liêu* provinces
(GSO, 2011)

In terms of shrimp aquaculture production, *Cà Mau* and *Bạc Liêu* provinces contributed to 30.39% of the total production in the Mekong Delta and 38.17% of the nation. Shrimp production increased significantly in the 2000 – 2004 period, and then increased a little bit in recent years (Figure 7).

As can be seen, small-scale shrimp farming in the Mekong Delta is an important source of income and likelihood for local farmers. However, this sector has been influenced by many factors including climate change in recent years. Especially, Mekong Delta is one of the world's most affected regions by climate change due to its geographical location and long low lying coastal region.

There are several types of shrimp farming models in the Mekong Delta, from extensive to intensive. The extensive or improved extensive is the largest system in terms of area and production. Improved extensive shrimp farmers practice a number of different systems including reliance on naturally occurring shrimp (*Penaeus merguiensis, P. indicus* and *Metapenaeus ensis*) post larvae or juveniles in the influent water, while others are stocking with hatchery reared tiger shrimp (*P. monodon*).

The study is implemented by the Research Institute for Aquaculture 2 (RIA2) and Can Tho University (CTU) under the project "Strengthening Adaptive Capacities to the Impacts of Climate Change in Resource-poor Small-scale Aquaculture and Aquatic Resources-dependent Sector in the South and South-east Asian Region". The main goal of the project is to identify and demonstrate the potential of integrated adaptation strategies to sustain small-scale aquatic farming systems under different climate change impact scenarios.

The study is focusing on farmers raising tiger shrimp (*P. monodon*) under improved extensive farming conditions. Farmers undertaking improved extensive farming also typically undertake polyculture of tiger shrimp with mud crab. Furthermore within the improved extensive tiger shrimp farming sector there are two broadly different systems, ie. with or without rice farming depending on salinity conditions. Farms with low salinity during the wet season culture rice during the low salinity period. Farms with high salinity throughout the year practice shrimp culture without rice culture.

1.5. Climate change (seasonal change, gradual change, Extreme events)

Aquaculture is vulnerable to direct and indirect effects of climate change on both wild fisheries and aquaculture (Figure 8).

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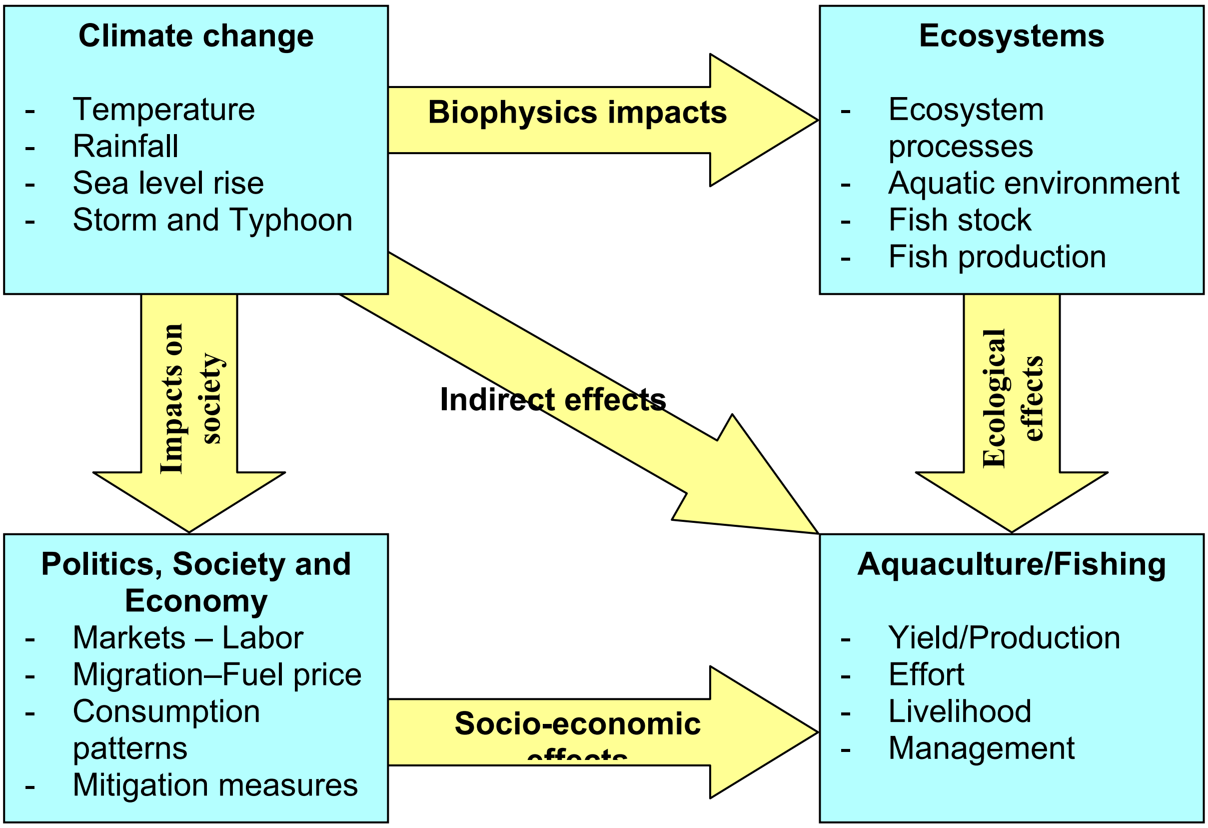


Figure 8: Climate change impacts on aquaculture and fisheries
(Daw et al. 2009)

Wild fisheries: The wild shrimp fisheries due mainly to the direct and indirect effects of climate change on the abundance and distribution of the wild stocks for the collection of wild broodstock and collection of wild fry. Farmers located coastal areas are more beneficial as they can get wild shrimp (*Penaeus indicus/merguiensis/spp*. and *Metapenaeus spp*.) into their farming pond. Moreover, local shrimp hatcheries have to take broodstock from the wild for spawning and nursery. In addition, alterations to mangroves, seagrasses and intertidal flats habitats are expected to be driven by increasing temperatures, sea-level rise, and variation in coastal currents and salinity regimes.

Aquaculture: (the farming operations and infrastructure). Changes to temperature and rainfall, and their effects on salinity and oxygen, can be expected to affect the reproduction, growth and survival of the fish as well as affect pond productivity. The direct effects of the projected increases in water temperature are likely to be beneficial to milkfish farming in the tropical Pacific. In particular, they are expected to

- lengthen the season in which wild fry are available for stocking ponds;
- extend the geographical range of milkfish spawning to higher latitudes;
- improve growth rate and so reduce the time to harvest.
- Improve Food Conversion Rate

Direct and indirect impacts:

Direct Impacts: There are direct effects of climate change for example the infrastructure for aquaculture ponds and water supply cannot be moved to prevent damage from severe weather conditions.

Indirect impacts: There are indirect effects of climate on the viability of aquaculture operations including the reduced availability and higher cost of feed ingredients due to the effects of the El Niño-Southern Oscillation (ENSO) on the supplies of fishmeal and the impacts of drought on crops.

Short term and long term impacts:

Climate change is the combination of short-term climate fluctuations, some of which can be seen as short-term trends, and long-term trends, because both are occurring together. Short-term climate fluctuations (including extreme events) are seasonal patterns and oscillations, such as the El Niño-La Niña Southern Oscillation (ENSO), as well as variable temperature patterns, heavy precipitation patterns (associated with cyclones, hurricanes, typhoons and monsoons) and severe storms.

Short-term climate fluctuations are those having increasing frequency and amplitudes, while what were formerly regarded as normal patterns become less frequent, and the near-term climate becomes more and more unpredictable. Extreme weather events are increasing in frequency and severity and occurring in wider areas. Extreme weather is defined with reference to the recorded historical distribution of a climatic event. Long-term climate change is defined as gradual climate change over decadal-scale timescales, including: sea-level rise; oceanic currents; gradual warming; acidification of open waters; and changes in the availability of freshwater.

The impacts of climate change on aquaculture could be positive or negative, arising from direct and indirect impacts on the farmed organisms and on the natural resources that aquaculture requires, especially water, land, seed, feed and energy. As fisheries provide significant feed and seed inputs for aquaculture, the impacts of climate change on them will also, in turn, affect the productivity and profitability of aquaculture systems. Handisyde et al. (2006) and De Silva and Soto (2009) reviewed the likely impacts of climate change on world aquaculture, including indirect impacts such as price fluctuations of competitive capture fisheries produce and impacts on the availability of fishmeal and fish oil.

Climate change will increase physiological stress in some farmed fish. This will not only affect productivity, but will also increase vulnerability to diseases and, in turn, impose higher risks and reduce returns to farmers. Interactions of fisheries and aquaculture sub-sectors could create other impacts. For example, extreme weather events could result in escapes of farmed fish and contribute to reductions in genetic diversity of wild populations, affecting biodiversity more widely. These impacts will be combined with other factors that affect adaptive capabilities, including: increased pressure from ever larger human populations on natural resources; political, institutional and management rigidity that negatively impacts the adaptive strategies of aquaculture-dependent communities; deficiencies in monitoring and early-warning systems or in emergency and risk planning; and other non-climate factors such as poverty, inequality, food insecurity, conflict and disease. However, positive impacts can also emerge from changes in farmed species, increased growth rate and productivity and possible improved Food Conversion Rate in the cooler season. These opportunities are not yet well understood. A community's ability to benefit will depend also on its adaptive capacity. Table 2 summarizes the main negative impacts and outcomes of climate change for aquaculture.

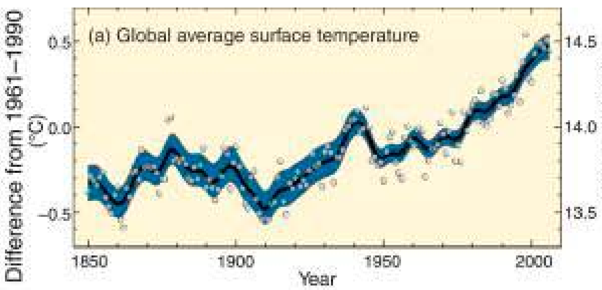
Table 3: Main impacts and outcomes of climatic change for aquaculture

Change	Impacts and outcomes
Short-term heat/ cold extremes	Hypoxia, heat and disease challenges kill fish and reduce productivity
Long-term warming	Reduced water quality, broodstock and seed availability and disease challenges force changes in farm locations; some fish grow faster, with better feed conversion and increase productivity
Sea-level rise	Coastal land is lost and eroded, damaging coastal ponds; salt water intrudes and forces relocation of freshwater farms, but increases brackishwater and marine farming areas
Ocean circulation	Variable supplies of fishmeal, fish oil and some low value/trash fish, sometimes increasing fish feed costs; availability of some wild seed is reduced
Acidification	Calcareous shell formation is compromised, especially for molluscs; water quality and plankton populations change, threatening fish health and potentially threatening reproductive processes of aquatic species
Precipitation	Predictability of water supply is reduced; flooding and droughts increase, compromising water supply and water quality, damaging farms, allowing fish escapes and killing fish; increased agricultural run-off can restrict safe harvesting from coastal aquaculture (e.g. oysters)
Severe storms; storm surges	Severe storms and storm surges increase in frequency and strength and in wider areas; farms are damaged with fish escapes and fish kills

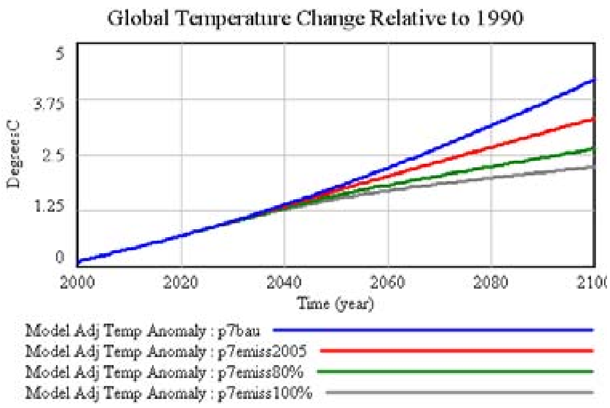
Most tropical and subtropical aquaculture is finfish culture in freshwater ponds. There are also widespread brackish water and marine ponds, farming penaeid shrimp, carnivorous marine finfish and some herbivorous/omnivorous species, such as milkfish and mullets. Aquaculture ponds are mostly one meter or less in depth and range in area from less than one hundred square meters to tens of hectares. Ponds are subject to large diurnal and seasonal changes in water temperature. The main factors that contribute to determining pond water temperature are water depth, solar radiation, air temperature, wind velocity, humidity, water turbidity and pond topography. Rapid changes in air temperature are reflected rapidly in pond water temperatures, causing stress, impacting productivity and in extreme cases, fish kills. Freshwater ponds are prone to droughts, flooding and water quality changes, as well as to saline intrusions when they are close to coasts. The large pond farms of the tropics and subtropics raise mainly carps, tilapias, catfishes, freshwater prawns, characins and snakeheads. Brackish water and marine ponds are prone to coastal erosion, storm damage and storm surges, as well as to large reductions in salinity after heavy rains or increase in salinity during droughts.

Temperature:

There is a sharp increase in observed global surface temperature (Figure 9). It is projected that there would be increase in about 0.2°C per decade (under SRES emission scenarios). Moreover, there would be a further warming of about 0.1°C per decade even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels (IPCC, 2007).



Observed change in global surface temperature IPCC (2007)



Global temperature change relative to 1990 (Internet)

Figure 9: Observed and projected change in global surface temperature

Similarly to the Mekong Delta, annual mean temperature would increase about 1.4°C (low emission scenario); 2.0°C (medium emission scenario); and 2.6°C (high emission scenario) by the end of 21st century compared to the average of the period 1980 – 1999 (MORE, (2009).

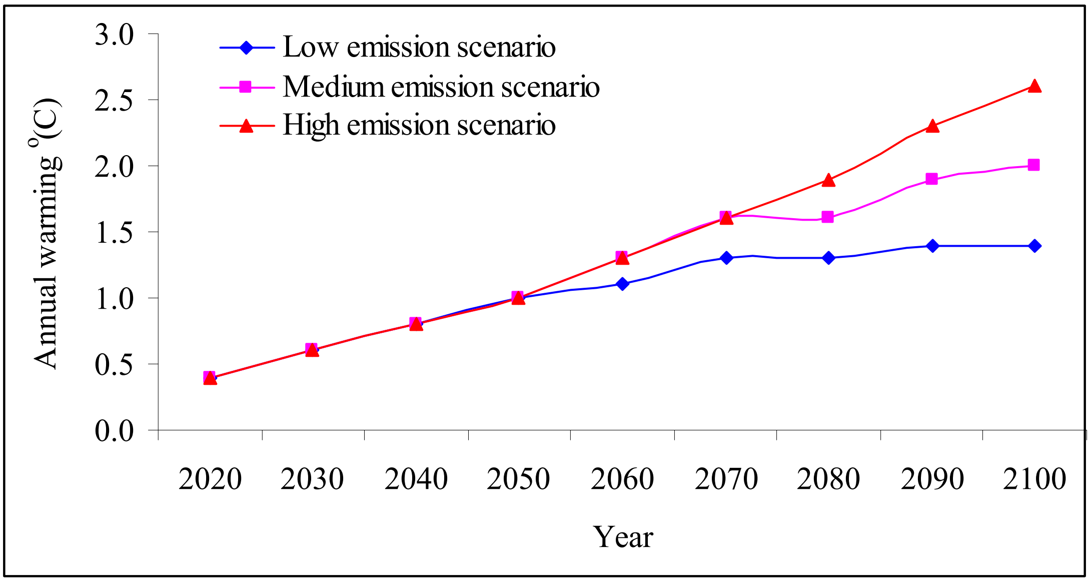


Figure 10: Temperature change relative to 1980 – 1999 in the South of Vietnam
MORE (2009)

The ecosystems in ponds are also sensitive to changes in water temperature. Higher temperatures can cause stratification, leading to algal blooms and reduced levels of dissolved oxygen. Shrimp can tolerate low dissolved oxygen concentrations but only for limited periods. They can avoid potentially lethal areas in stratified ponds but this reduces the volume of available habitat and increases the stress on fish congregated in non-lethal areas. Heat stress can also occur due to elevated temperatures and is exacerbated in shallow-water ponds (< 50 cm deep) compared with deeper-water ponds (100–200 cm deep), where they can 'escape' by staying lower in the water column during summer and moving towards the surface in winter.

The life cycle of the black tiger shrimp in the wild (brackish and marine water) are expected to be affected by increases in sea surface temperature and increases in pond water temperatures. Warmer surface water temperatures in ponds are projected to increase growth rates, and improve the efficiency of food conversion ratios, but have adverse environment impacts.

Typhoons and cyclones:

Generally, there are fewer typhoons and cyclones in the Mekong Delta. There are only 12 typhoons influencing directly in coastal area of the South of Vietnam during 45 years (1961 – 2006). Typhoons usually occur in October to December. These extreme events can cause intensive damages (damage to ponds and other farm infrastructure, and the escape of shrimp through overflow of pond dykes by rising waters) by heavy raining and flooding that are expected to be a threat to ponds constructed close to the coast or close to rivers.

In addition, annual rainfall in the Mekong Delta would increase about 1 – 2% (Figure 11). Moreover, rainfall in the middle of the dry season would decline 7 – 22%. Meanwhile, rainfall in the middle of the wet season would increase about 1%.

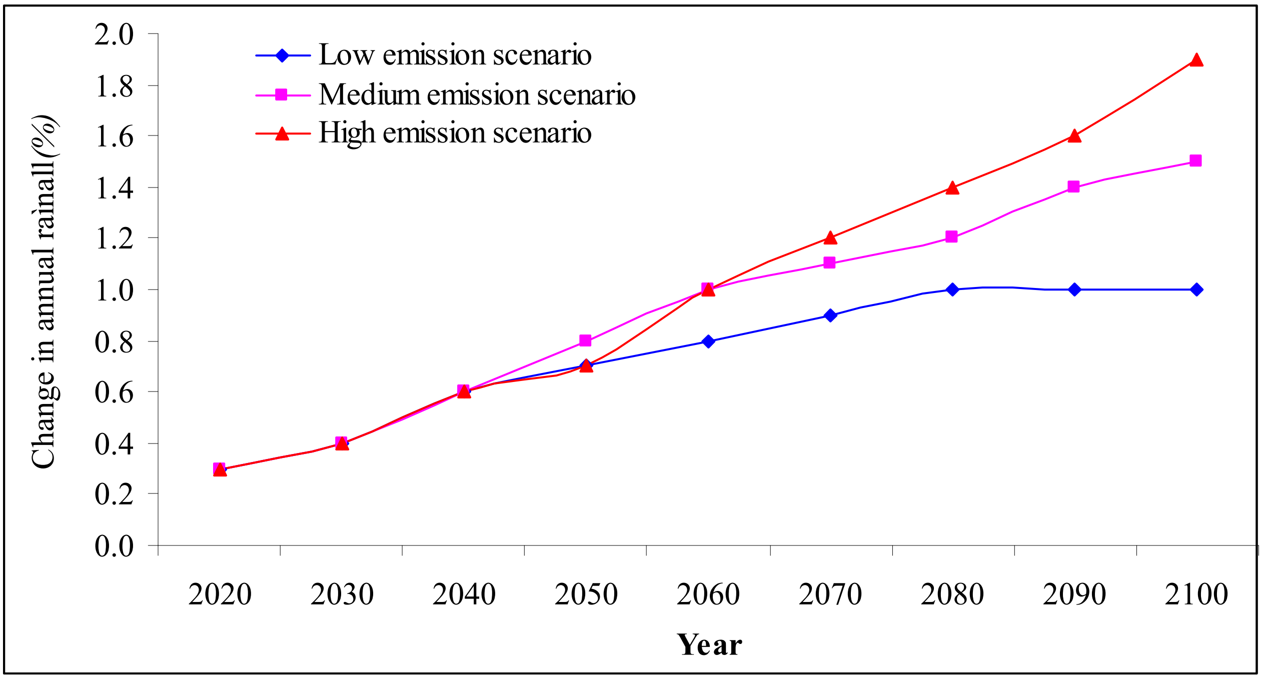
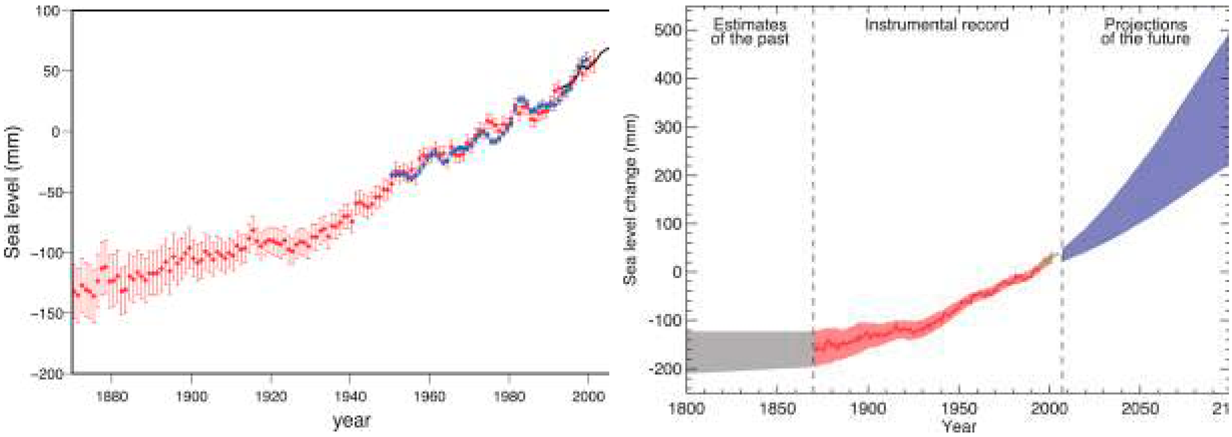


Figure 11: Change in annual rainfall (%) relative to 1980 – 1999 in the South of Vietnam

MORE (2009)

Sea level rise:

There is strong evidence that global sea level has been increasing. Especially, it is projected that sea level would continue with a greater rate in the 21st century. It is estimated that sea level may rise about 26 – 59cm by 2100 (IPCC, 2007) (Figure 12).



Annual global mean sea level　　Global mean sea level observed and projected

Figure 12: Global sea level change
IPCC (2007)

Sea level in Vietnam was also projected to increase. Sea level may rise about 28 – 33cm by 2050 and about 65 – 100cm by 2100 relative to the baseline period of 1980 – 1999 (Figure 13).

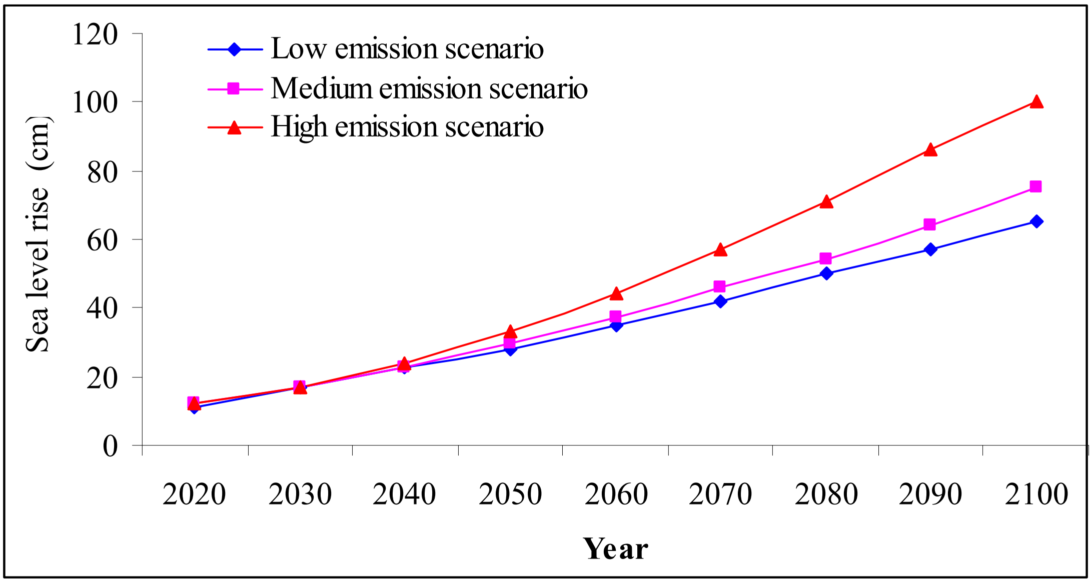


Figure 13: Sea level rise relative to 1980 – 1999 in the South of Vietnam
MORE (2009)

Moreover, inundated maps of the Mekong Delta were created at different sea level rise scenarios (Figure 14). There would be 12.8% flooded area of the Mekong Delta under sea level rise at 65cm scenario; 19% (sea level rise at 75cm scenario) and 37.8% (sea level rise at 100cm scenario).

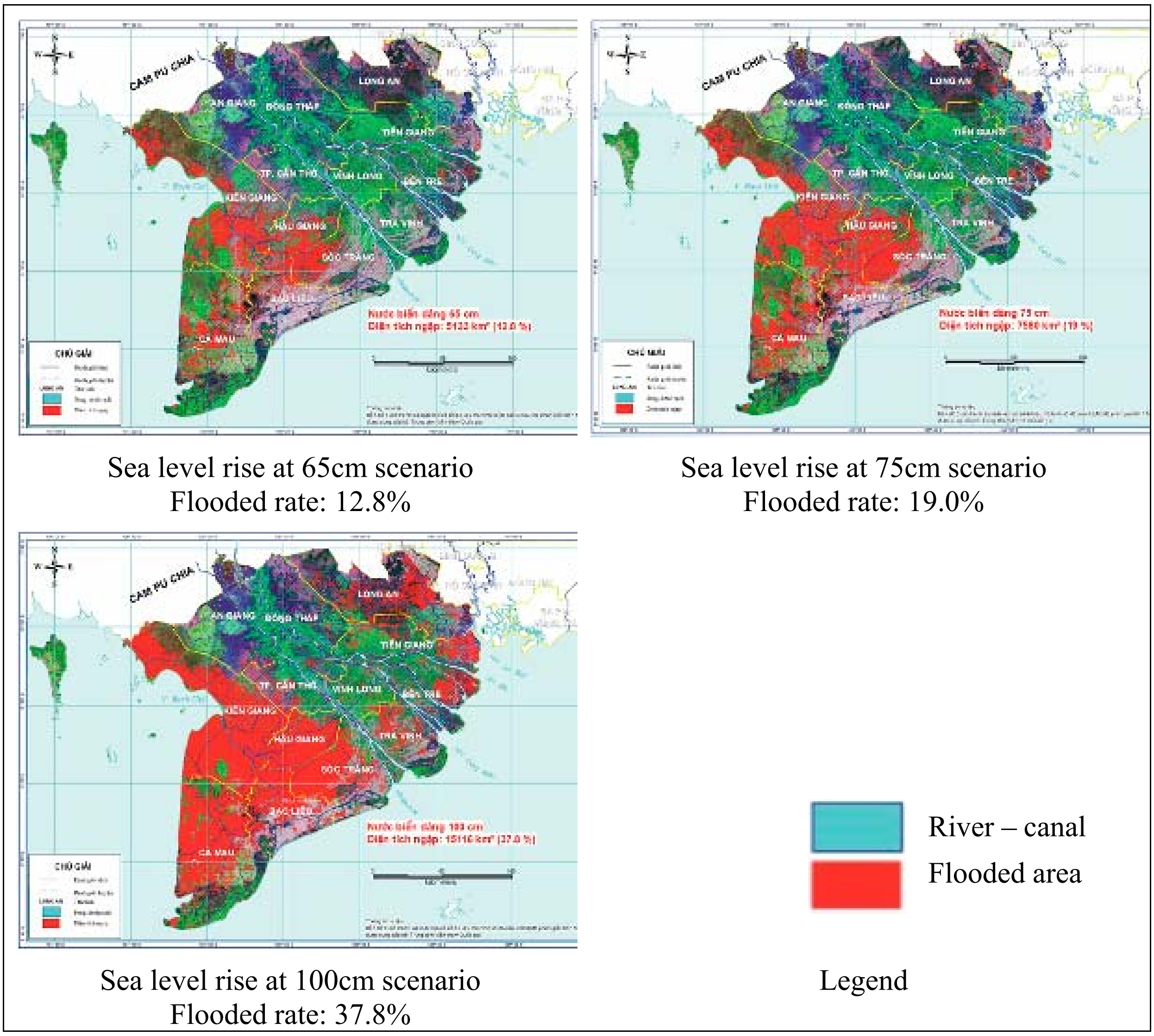


Figure 14: Inundated map of the Mekong Delta at different sea level rise scenario
MORE (2009)

The main effects of sea-level rise on shrimp ponds that could potentially have an impact on the profitability of farming.

Infrastructure:

- Increased wave erosion of coastal dikes
- Increased incidence and height of storm surge damaging dikes
- Increased flooding due to combination of increased sweater level and river level

Operation:

- Inhibiting outflow of wastewater,
- Inability to lower pond levels for harvesting,
- Loss of capacity to prepare emptied ponds before restocking

1.6. Climate model and scenario selection

Vietnam is one of the world's most five climate change affected countries (Dasgupta et al., 2007), especially in the Mekong Delta due to its geographical location and long low lying and deltaic coastline and dependence of the local people as their likelihood and food security. There are likely more and more weather extreme events that alter interactions of toxicants with environmental parameters causing highly varied temperature, precipitation, salt water intrusion and sea level rise.

It is advised that scenario at medium levels should take for considerations in the development of action plans and mitigations to respond to climate change due to the complexity and limitation of understanding of climate change.

Decision-makers and resource managers require information regarding future changes in climate average and variability to better anticipate potential impacts of climate change. However, in order to formulate adaptation policies in response to climate change impacts, reliable climate change information is usually required at finer spatial scales. Although GCMs provide adequate simulations of atmospheric general circulation at the continental scale they do not capture the detail required for regional and national assessments. The ability of the model to simulate the present climate conditions is an important consideration taken into account in the selection of GCM used in this study. In general, GCMs are validated for their ability to reproduce spatial patterns (McKendry et al. 1995, Huth 1997) of selected variables and their annual cycles (Nemesova & Kalvova 1997, Nemesova et al. 1999).

As climate models have developed, there has been a general tendency toward increased spatial resolution. Worlclim provides a number of outputs that have been statistically downscaled from global climate models. WorldClim provides projected climate data over the global land areas in geodetic coordinate system and in four different spatial resolutions; the highest of which is 30 seconds or about 0.86 km2 at the equator. A resolution of 1 km was used for the case study areas (in Viet Nam, Philippines and India) to provide more detail. Data at this resolution will take a little more time to process the data the first time but it will be done only once and will allow detailed analysis for the case study areas and other areas in the future. Because the models are global, they can "wash out" finer distinctions at the regional scale.

A requirement for the inclusion of a model in climate projections is that it adequately simulates present-day climate conditions. Therefore, statistical methods were used to test the reliability with which individual models simulate observed climate conditions over the Asia/Pacific region. Having described some of the options available for climate model and scenario selection and the information available from the WORLDCLIM and IPCC Distribution Center, the next vital step in an impact assessment is the choice of model to be used. An initial selection of experiments from three modelling centers was made based on their availability, resolution and performance. In this study, we assessed the performance of three climate models (HadCM3, CSIRO and CCMA) using two statistical metrics. Correlation pattern and RMSE of the three climate variables (rainfall, temperature, MSLP) were extracted and compared. Pattern correlation from the three models shows significant results indicating it was able to simulate the pattern of rainfall, MSLP and temperature in the Asia Pacific region, however the choice was narrowed down to one after ranking which has the highest correlation pattern in all the seasons evaluated. Correlation pattern for the three parameters are higher in CSIRO compared with HadCM3 and CCMA in majority of the seasons evaluated. Based on the correlation pattern of the 3 GCM models it is recommended that CSIRO Climate model be used in this study, however it is also prudent to consider the output of the three models available in the Worldclim in future studies because of the uncertainties inherent in any individual climate projection.

Emission scenario's is identified as one of the major cause of uncertainty in projected future climates. Inherent uncertainties exist in the key assumptions in regard to relationships between future population, socioeconomic development and technical changes, which form the base for the IPCC SRES Scenarios. Making climate projections for a range of SRES scenarios such as the presently available in Worldclim, A2 and B2 emission scenario families can be one way to consider the uncertainties in emission scenarios. B2 emission scenarios for carbon dioxide emission rates are more than double in A2 scenario as compared to A1B and B2 scenarios towards the end of the century. B2 scenario may be a more realistic scenario, particularly after the recent credit crunch and specifically A2a (business as usual) and is the recommended choice.

Chapter 2 – Farmer Perceptions of Climate Change

This chapter is the result of the Focus Group Discussion (FGD) in the workshop organized on the 15 – 16th October 2009 and 27th March 2012 in Cà Mau province with attendance of shrimp farmers and local authorities in *Cà Mau* province and farmers in *Bạc Liêu* province, scientists (RIA2 and CTU) and international partners/advisers (Bioforsk, Akvaplan-niva, Kasetsart University). These provinces have a large proportion of land under shrimp farming. The shrimp farmers participating in the discussion are operating a range of production systems (small improved extensive, large improved extensive, small intensive and large intensive) with the majority being those operating improved extensive (the most widely used production system in use in the study area).

Participating farmers were grouped for discussion to identify climate change factors and determine impacts of each factor to their farming system. Moreover, farmers also asked how to adapt to the impacts of climate change.

Figure 15: Farmer group discussion in Cà Mau

The objective of the discussion is to understand and link shrimp farmer's perceptions about climate change to impacts on their farming system or farm production, the economic impacts and ways to adapt to these changes in climate and their affects. In addition, these methods help to map the farmers' knowledge and experience from the region and use the knowledge in future planning of adaptation strategies.

Participation approach can be used to integrate knowledge, experience of stakeholders to identify the problems, needs and priorities and to enhance the quality of solutions for adaptation (Clark, 1996; Renard, 1986). The methodology used in the present study was a participatory rural appraisal (PRA) where participants, including Tiger shrimp farmers and other stakeholders were encouraged to share their experience, perceptions and ideas about impacts, vulnerability and adaptation of shrimp aquaculture climate change in Vietnam.

The PRA techniques used were FGD and mapping crop seasonal calendar, to capture qualitative information, in combination with quantitative data collection such as risk assessment, farm production and economic information. Semi-structured and facilitated FGD with only farmers and then with other key stakeholders were used to allow flexibility during the discussion but keep the discussion about the topic. This technique was used to understand farmer's perception of climate changes, their impacts on their farming production and appropriate adaptation measures to respond to these climate changes (Annex 1).

2.1. Farmer perceptions of climate change

Farmers in both provinces have already observed irregular weather pattern and extreme events for the last decades and these events recently become a very well-known term as climate change. Farmers' perceptions of climate change are similar in both provinces because the two provinces neighbor each other. Generally, impacts of climate change on shrimp farming can be summarized in Figure 16.

Farmers in *Cà Mau* province identified 4 events of climate change impacted their shrimp farming: hot weather, water level rise, storm, and irregular seasonal changes. Whiles the key climate change impacts observed by farmers in *Bạc Liêu* province were identified as too much rain, water level rise, high temperature, storm, and irregular seasonal change.

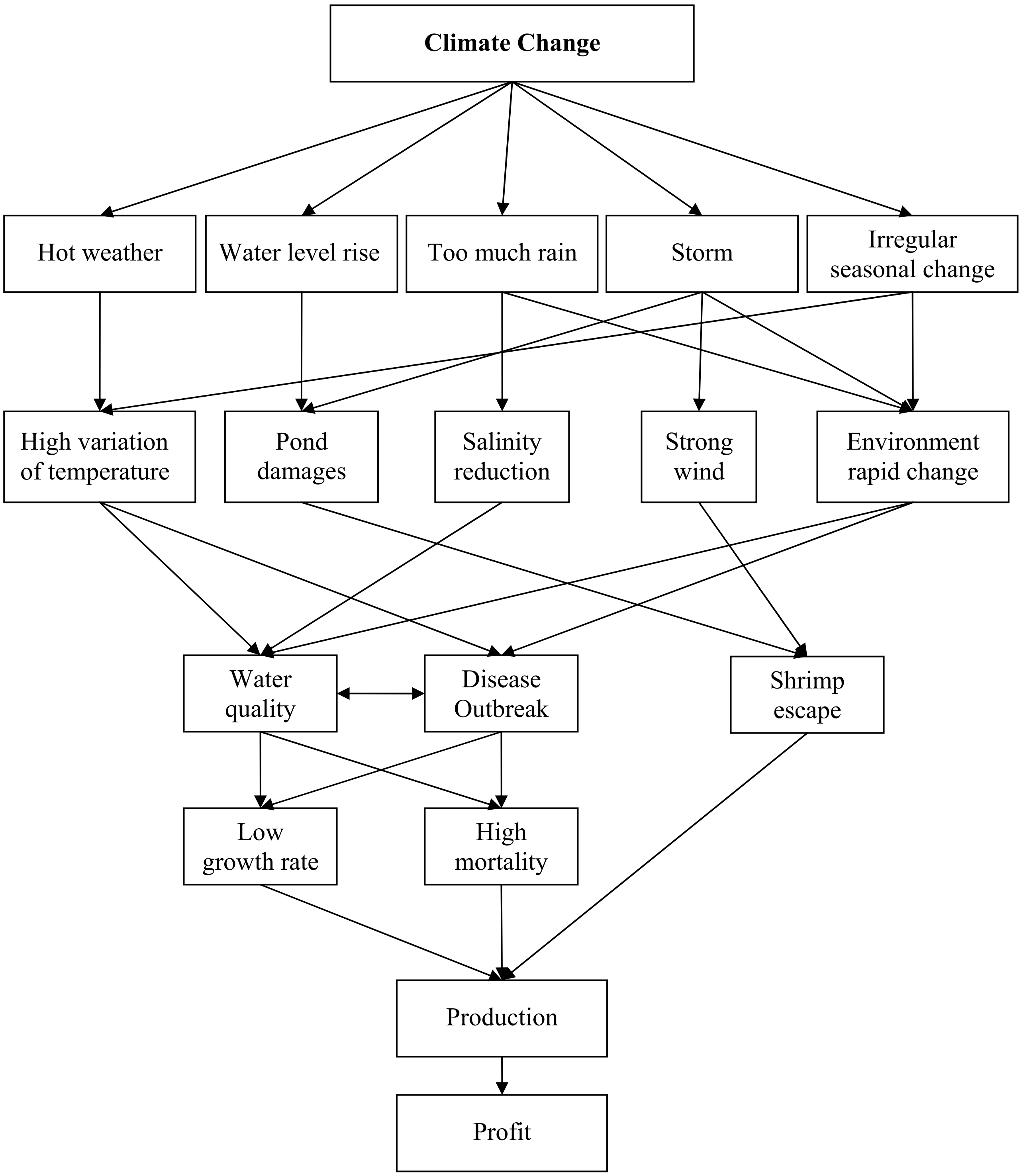


Figure 16: Impacts of climate change on shrimp farming

In *Cà Mau*, hot weather was considered to be the highest impact to shrimp farming, followed by sea level rise, storm and irregular seasonal change. On another hand, farmers in *Bạc Liêu* rate high risks to their shrimp farming as too much rain, high temperature and sea level rise. Temperature usually changes seasonally: high in the dry season, especially from March to June and low during the wet season (Figure 17).

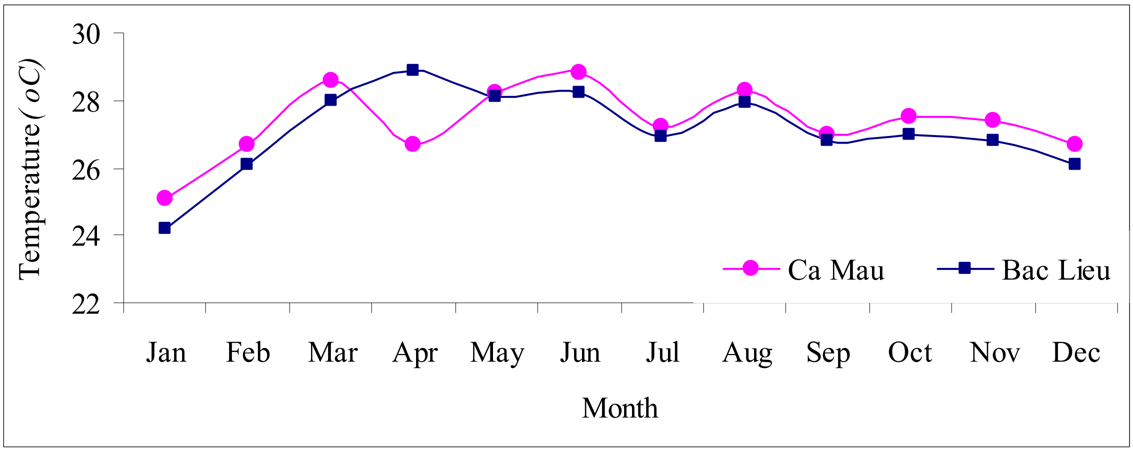


Figure 17: Monthly average temperature variation in 2009

Variation in temperature is similar in *Cà Mau* and *Bạc Liêu* provinces due to neighboring each other. Annual temperature in 2009 was 27.4°C in *Cà Mau* province and 27.1°C in *Bạc Liêu* province. Similarly, variation in sunshine duration and rainfall are almost the same between the two provinces and change seasonally (Figure 18 and Figure 19).

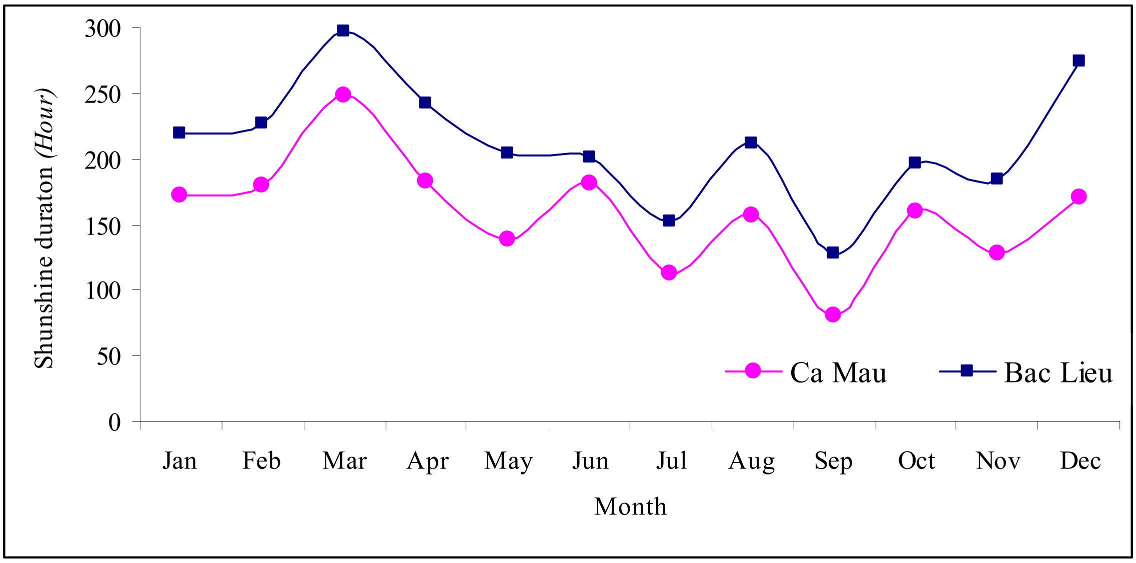


Figure 18: Monthly average sunshine duration in 2009

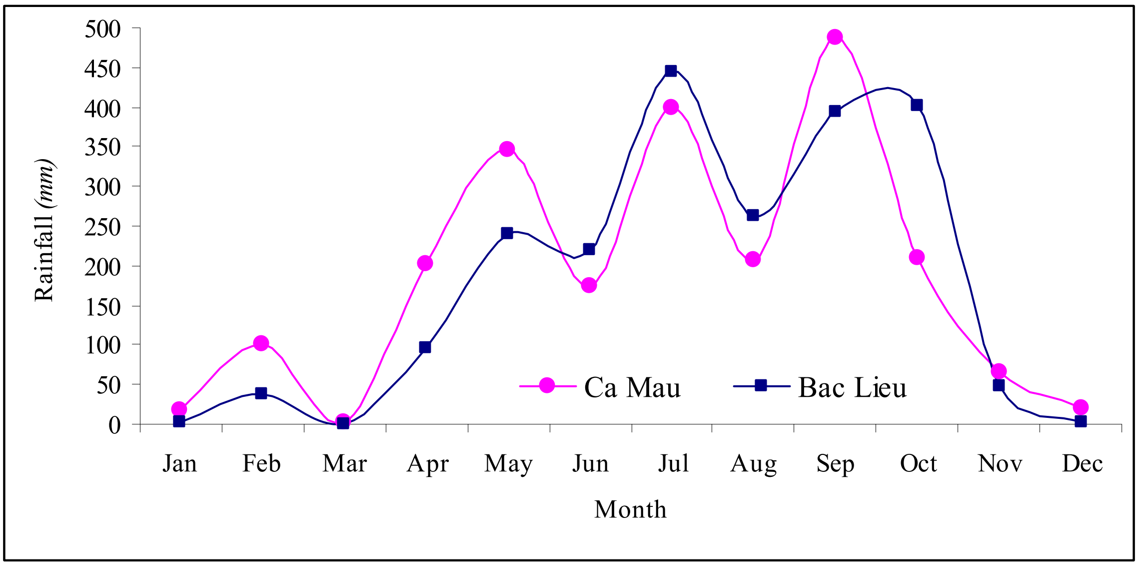


Figure 19: Monthly average rainfall variation in 2009

Moreover, tide impact in *Bạc Liêu* province is quite stronger in *Cà Mau* as *Bạc Liêu* territory is mainly influenced by east sea with tidal amplitude of 3 – 4m (Figure 20) while *Cà Mau* is located in a transition area between east sea and Gulf of Thailand which has lower tidal amplitude (1 – 2m). Therefore, tide surge sometimes affects pond damages such as dyke, sluice gate and pond facilities. This leads to shrimp loss to outside.

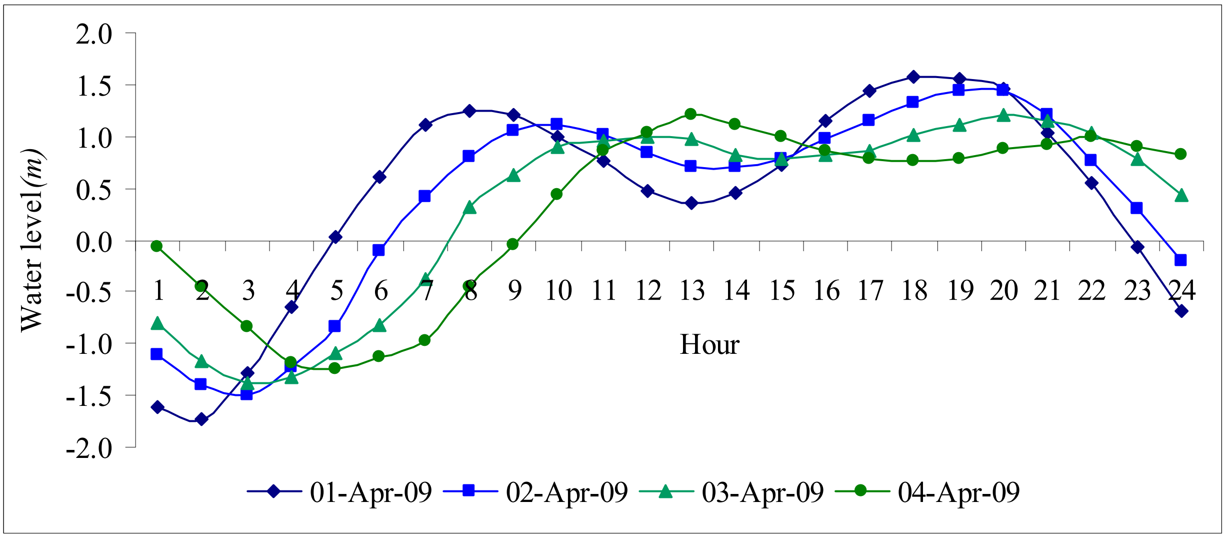


Figure 20: Water level variation by hour in *Ganh Hao* station (*Bạc Lieu* province)

2.2. Impacts of climate change

Farmers in both provinces have recognized the impacts of climate changes on their shrimp farming. Generally, climate change has affected the water quality with high fluctuation of temperature, salinity, high toxic gas and algae or caused contamination of water. As a result, shrimp have showed some stresses, loss appetite, slower molt and growth performance or even dead. For example, high (variation) temperature leads to increased salinity in the ponds and leading to shrimp affected by toxic gas and algae, and low dissolved oxygen.

In addition, high rainfall/storm also caused temperature and salinity drop, leading to stress and outbreak of some diseases. In the meantime, dyke/canal/sluice gates may be damaged or destroyed, then shrimp can escape from the ponds and contamination from outside worsen the condition of the pond water quality. Impacts of climate change on shrimp farming are detailed in Table 4.

Table 4: Impacts of climate change on shrimp farming

Climate change	**Impact**
1. Hot weather	- High variation of water temperature (day/night) - Variation other factors: salinity, pH, oxygen… - Feeding and growth performance - Respiratory and immune system - Molting, shocking, diseases - Mortality
2. Sea level rise	- Sluice gate/dyke damages - Pond facility damages - Escape of shrimp to outside (loss production) - Flooding - Pollution - Pond preparation
3. Rainfall	- High water quality variation: pH, temperature, salinity, alkalinity, oxygen, water stratification - Soft shell - Pond erosion - Feeding and growth performance - Immune system
4. Storm and Typhoon	- Heavy rain, flooding and wind - Suddenly change water environment - Dike/sluice gate erosion and damage - Loss of production - Mortality - Diseases spread
5. Irregular seasonal change	- High variation environment: temperature, alkalinity, pH, salinity, oxygen… - Diseases occurrence/outbreak/spread - Feeding and growth performance - Mortality

It can be seen that temperature variation is an important factor influenced to shrimp farmers. Several related factors can cause rapid change in temperature such as too much rain, irregular seasonal change weather *etc*. This makes shrimp get stress and diseases, finally affects to the farmers' profit.

Extreme hot temperature for several days (perceived by farmers as a recent climate change that has impacted on their shrimp farming production) has led to increase in surface heat and high temperature fluctuation between day and night times. In the same line with a study conducted by World Fish Centre (2009), the hot temperature increased harmful algal blooms that released toxins in the water, reduced dissolved oxygen, spread of pathogens, and threaded fish health and growth.

In addition, higher temperatures tends to accelerate the rate of nutrient recycling, further stimulating phytoplankton production/bloom and potential deposition, and drive oxygen concentrations even lower (Najjar *et al*., 2010). Harmful bacteria respond to temperature changes, some heterotrophic bacteria, like the *Vibrio* species, are associated with serious illnesses (Najjar *et al.*, 2010). *V. cholera* and *V. parahaemolyticus* appear to be associated with elevated sea surface temperature (McLaughlin *et al*., 2005). Most marine *Vibrios* can be found associated with a variety of phytoplankton, zooplankton, changes in densities and environment niches of these organisms are directly influence the proliferation of *Vibrio spp*. (*Marques et al*., In Press). Prolonged high temperature during dry seasons and droughts caused salinity intrusion, which directly changed the biodiversity degree in a certain area. An increase in salinity intrusion in the Mekong Delta region resulted in changes to crop patterns and productivity, and negative effects on aquatic and terrestrial ecosystems, and then a higher prevalence of infectious diseases is also forecasted (MRC, 2009).

Moreover, temperature and precipitation are claimed to have the largest influence on the partitioning of chemical toxicants (Noyes, *et al.,* 2009). Therefore, high temperature and or too much precipitation can result in a poor environment and high toxicity for shrimp. In poor environments shrimp may exhibit the symptoms of infectious diseases such as black gills, corrosion of appendages, brown or black spots on the carapaces and shell.

Farmers believe that shrimp disease happened more frequently due to rapidly changing water conditions under the effects of climate change. Changes in salinity can affect aquatic organisms as a direct stressor as well as by altering the bioavailability and increasing the toxicity of some chemicals (Noyes, *et al.,* 2009). An increased contaminant bioavailability and toxicity is possible in estuaries and coastal ecosystems subject to increased salt water intrusion or droughts (Noyes, *et al.,* 2009).

Irregular rain can cause poor conditions for shrimp culture. Prolonged and continuous rain directly affects salinity concentration, and may create favorable conditions suitable for disease outbreaks. According to Eastham et al., (2008), the annual precipitation in the Mekong basin increased by 200 mm, equivalent to 15.3%, predominantly in wet seasons, and also increased in dry season. High levels of precipitation may also cause water to rise to levels where pond banks are overtopped, leading to shrimp escapes from ponds as well as contamination from the outside environment resulting in diseases.

Ca Mau is vulnerable to climate change, according to the stakeholders' perceptions. A number of farmers along the *Ca Mau* coast are dependent on shrimp farming for livelihoods. In fact, Shrimp farming has increased in the region due to salt water intrusion. This shows that climate change in some ways can be positive to livelihoods. A mix of rice and shrimp farming has increased in the region, which is positive. But this may not be the case always. Measures to protect the coast should be initiated at the individual and community level, in a coordinated way. This is an opportunity for the regional government agencies to work together with people, through increasing awareness, training and education, investments to develop infrastructure to protect the coast and land, and thereby reduce vulnerability.

An analysis of recent climatic data on the Mekong delta showed that temperature trend is towards increasing and becoming more variable (hotter in summer and colder in winter) and that precipitation will increase particularly so in the wet season (Schäfer, 2004). According to Eastham *et al.,* (2008), the annual precipitation in the Mekong basin increased by 200 mm, equivalent to 15.3%, predominantly in wet seasons, and also increased in dry season.

Production and economic impacts of individual farmers from climate change impacts (farmers were generally unable to quantify impacts for each separate climate change impact) included reduced production amount or reduced/similar production amount but smaller shrimp size and reduce profit due to lower price for smaller shrimp.

All farmers have been affected their farming by climate change at different levels. The results from the farmer focus group discussion with 13 participants in *Cà Mau* province show that farmers can loss their shrimp production up to 60% due to impacts of climate change (Figure 21) in recent years. On the other hand, they had to spend more money on infrastructure of their ponds, chemical (lime, probiotic…) for treatment and other preparation costs. As a result, there was a substantial increase in total cost. This leads to a significant decrease in income (Figure 21). On the average, there are about 44±16.28% decrease in production and 57±20.40% decrease in income due to climate change impacts.

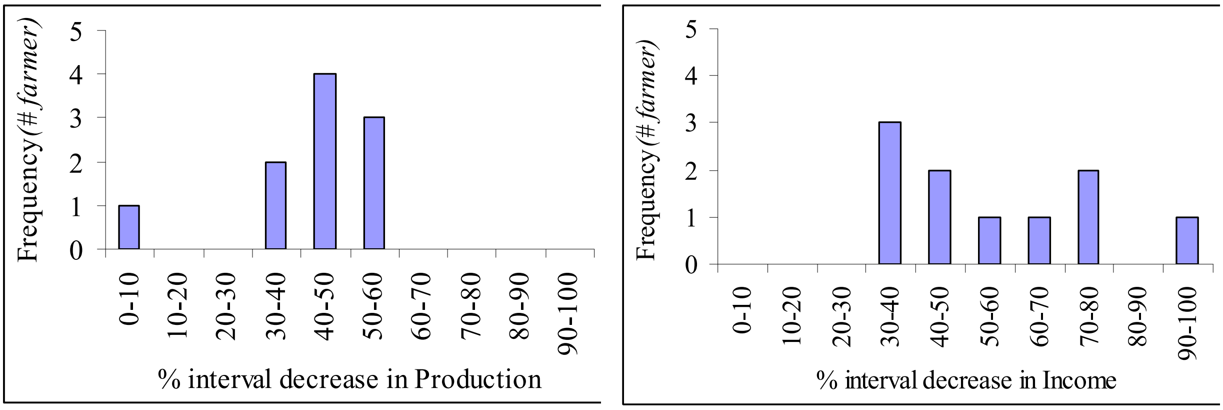


Figure 21: Production and economic losses due to climate change impacts in *Cà Mau* province

Similarly in *Bạc Liêu* province, shrimp farmers usually loss up to 27% of production and 20% of income due to impacts of climate change. One farmer spent more 20 million VND (about 1,000USD) for sluice gate reparation and 40 million VND (about 2,000USD) for dyke improvement every two years in recent years. Another farmer also spent more 14 million VND (about 700USD) for dyke improvement due to storm and sea level rise. About the impact of temperature (too high), others farmer spent more 20 – 30% of the total costs on electricity for paddy wheel and probiotic for water treatment. That makes farmers' profit smaller and affects significantly local shrimp farmers.

2.3. Seasonal and crop calendar

Shrimp farming in the lower Mekong delta is practices in with a number of different production systems ranging from large scale intensive, semi-intensive and extensive. The extensive or "improved extensive" where some modifications/improvements have been made to the pond system, is the largest production system type by area and production and is largely characterized by small-scale farmers with <3ha in farm area per farmer/family (Be *et al.*, 2003).

Improved extensive shrimp farmers practice a number of different systems including reliance on naturally occurring shrimp (*Penaeus merguiensis*, *P. indicus* and *M. ensis*) post larvae or juveniles in the influent water, others stocking with hatchery reared *P. monodon* (Brennan *et al.,* 2002). Shrimp farmers attended in the workshop all raise *P. monodon* under improved extensive farming conditions.

Some farmers are known to add chemicals and or supplemental feed into the pond (Brennan *et al.,* 2002). The higher inputs systems is characterized by higher return but also higher (Shrimp mortality) risk (Be *et al.,* 2003). The theoretical assumption is that, the level of inputs can be dependent on the economic situation of the farmer, poorer farmers being financially unable to purchase these inputs even if they believe that they are beneficial for production.

In areas where source of water is largely freshwater in the rainy season and brackish in the dry season, farmers typically practice rice fish culture, growing a crop of rice concurrently with shrimp in the wet season and only shrimp in the dry season. In areas where brackish and saline water occurs thought the year crops of shrimp only are typical. Improved extensive tiger shrimp farmers typically practice multiple (bi-monthly or monthly) stockings and harvests.

Rice shrimp farming in the Mekong delta is enabled by saline water intrusion and occurs in margin areas of the saline water intrusion that has freshwater in the rainy season and brackish water in the dry season. Shrimp farming in rice fields in the salt water intrusion zone has been expanded by the central government and has led to a rapid increase in area under culture and production from this sector.

Production system design is the typically rice paddy field with an improved (increased size) outside pond dyke and a trench just inside the pond dyke. The trench around the edge of the rice field reduced the rice growing area but also provides refuge for shrimp from water quality (temperature, salinity, etc…) fluctuations in the rice growing area.

Tiger shrimp (*P. monodon*) have a high capacity to assimilate and grow quickly on natural production in aquaculture ponds. Studies show that artificial feed is not very efficiently utilized by tiger shrimp when pond natural productivity is high and that the majority of body composition is derived from the natural productivity on the pond bottom (Burford, 2003). Tiger shrimp also have obtained good market prices making them good candidates for extensive culture systems.

The seasonal and crop calendar of shrimp farmers in *Cà Mau* province is presented in Table 5. Shrimp farmers in the discussion group practice either rice shrimp or shrimp only cropping but only have minor differences in crop calendars. Both rice and rice shrimp farmers practice multiple stocking and multiple harvest throughout the year (except during the pond preparation month (August) for shrimp only farming). Shrimp market price varies during the year with high prices in December and January and low prices in June and July.

Seasonal and climate factors are in Table 5 as follows: heavy rains are observed in August to October; it is too hot during March and April; it is too cold in January and December; Storms occur in October and November followed by wind in December. No seasonal weather or climate factors were identified by farmers during May to July coinciding with low shrimp prices, conversely many seasonal weather or climate factors with identified by farmers in August to April (high prices for shrimp occurring in the middle of this period in December and January). Seasonal calendar is meant to provide information on the type of activities farmers carry out in a particular month, and the corresponding weather conditions. The results could be useful to plan for better adaptation measures.

Table 5: Seasonal and crop calendar for shrimp farming in *Cà Mau* province

Items	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Weather conditions												
1. Rain (x) heavy rain (xx)	-	-	-	-	x	x	x	xx	xx	xx	x	x
2. Too hot (h); too cold (c)	c	-	h	h	-	-	-	-	-	-	-	c
3. Storm (x)	-	-	-	-	-	-	-	-	-	x	x	-
4. Wind (x)	x	-	-	-	-	-	-	-	-	-	-	x
Crop calendar: Rice – Shrimp												
1. Rice (r) shrimp (s)	s	s	s	s	s	s	s	rs	rs	rs	rs	s
2. Pond preparation (x)	-	-	-	-	-	-	-	x	-	-	-	-
3. Stocking shrimp (x)	x	x	x	x	x	x	x	x	x	x	x	x
4. Harvest (x)	x	x	x	x	x	x	x	x	x	x	x	x
5. Price of shrimp	H	-	-	-	-	L	L	-	-	-	-	H
Crop calendar: Shrimp only												
1. Pond preparation (x)	-	-	-	-	-	-	-	x	-	-	-	-
2. Stocking shrimp (x)	x	x	Hx	Hx	Hx	Hx	Hx	-	Lx	Lx	Lx	Lx
3. Harvest (x)	x	x	x	x	x	x	x	-	x	x	x	x
4. Price of shrimp	H	-	-	-	-	L	L	-	-	-	-	H

(H: High; L: Low)

The seasonal and crop calendar of shrimp farmers in Bạc Liêu province is presented in

Table 6. *Bạc Liêu* shrimp farmers in the discussion group practiced three general farming systems: Single crop per year intensive farming, two crops per year intensive farming and improved extensive farming with year round cropping and harvesting.

Single crop intensive shrimp farmers practice pond preparation in December and January, stock between February and June when seed price is low in February, May and June and high in March-May. They then harvest between July and January obtaining high prices between November to January and low prices July to October with the lowest in September.

Two crop per year intensive shrimp farmers practice pond preparation in December and July, stock in February and August and harvest in June and December.

For both intensive systems (one and two crops per year), high feed costs in April to June and disease problems with WSSV typically occur from February to April and from August to October and disease problems from May to June and from November to December.

Improved extensive shrimp farmers practice pond preparation from September to November, stocking from December to August with peak stocking occurring in December and April. Harvesting occurs year round with less occurring in pond preparation months (September to November). Disease problems with WSSV typically occur from December to June.

Table 6: Seasonal and crop calendar for shrimp farming in *Bạc Liêu* province

Items	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Weather conditions												
1. Rain	-	-	-	-	x	x	x	x	xx	xx	x	x
2. Dry	x	x	xx	xx	-	-	-	-	-	-	x	x
3. Water temperature	-	-	H	H	-	-	-	-	-	-	L	L
4. Storm	-	-	-	-	-	-	-	-	-	xx	x	-
5. Tide	-	-	-	-	-	-	-	-	-	-	xx	x
Crop calendar: Improved extensive farm												
1. Pond preparation	-	-	-	-	-	-	-	-	x	x	x	-
2. Stocking	x	x	x	xx	x	x	x	x	-	-	-	xx
3. Seed price	-	-	H	H	-	-	-	-	-	-	-	-
4. Harvest	x	x	x	x	x	x	x	x	x	x	x	x
5. Price of shrimp	H	-	-	-	-	-	-	-	-	-	-	H
6. Disease	ws sv red	ws sv red	ws sv red	ws sv red	ws sv red	ws sv red	-	-	-	-	-	ws sv red
Crop calendar: Intensive Shrimp (1 crop/year; 6 month/crop)												
1. Pond preparation	x	-	-	-	-	-	-	-	-	-	-	x
2. Stocking	-	x	x	x	x	x	-	-	-	-	-	-
3. Harvest	x	-	-	-	-	-	x	x	x	x	x	x
4. Seed price	-	-	L	H	H	L	L	-	-	-	-	-
5. Price of shrimp	H	-	-	-	-	-	L	L	L	L	H	H
Crop calendar: Intensive Shrimp (2 crop/year; 5 month/crop)												
1. Pond preparation	x	-	-	-	-	-	x	-	-	-	-	-
2. Stocking	-	x	-	-	-	-	-	x	-	-	-	-
3. Harvest	-	-	-	-	-	x	-	-	-	-	-	x
4. Feed price	-	-	-	H	H	H	-	-	-	-	-	-
5. Disease	-	ws sv red	ws sv red	ws sv red	bla ck gill	bla ck gill	-	ws sv red	ws sv red	ws sv red	bla ck gill	bla ck gill

(H: High; L: Low; WSSV: white spot syndrome virus)

2.4. Risk assessment

Shrimp farmers in each province were asked to categorize the likelihood of occurrence for each of the climate change impact (1: rare to 5: almost certain). Then each farmer also is asked to categorize the consequence for each of the climate change impact (1: insignificant to 5: Catastrophic). Scores then were added up for each risk to identify the highest risks (Annex 1).

The *Cà Mau* farmers' perception of the climate changes likelihood and consequence and thus risk rating is presented in

Table **7**.Irregular weather had the highest risk rating and considered a "high" risk, others in decreasing risk rating order were hot weather, storms and water level rise and were all considered "medium" risk (Table 8).

Table 7: Risk priority matrix of extreme events in *Cà Mau* province

Climate change impact	Commune	District	Consequence	Likelihood	Risk
1. Hot weather	Hoà Mỹ	Cái Nước	3	5	15
	Tân Duyệt	Đầm Dơi	2	5	10
	Average		*2.5*	*5*	***12.5***
2. Sea level rise	Hoà Mỹ	Cái Nước	2	5	10
	Tân Duyệt	Đầm Dơi	1	5	5
	Average		*1.5*	*5*	***7.5***
3. Storm	Hoà Mỹ	Cái Nước	4	3	12
	Tân Duyệt	Đầm Dơi	5	1	5
	Average		*4.5*	*2*	***8.5***
4. Irregular season	Hoà Mỹ	Cái Nước	4	4.5	18
	Tân Duyệt	Đầm Dơi	5	4	20
	Average		*4.5*	*4.25*	***19***

Table 8: Likelihood and consequence rating of climate change observed by farmer in *Cà Mau*

Likelihood	**Consequence**				
	1. Insignificant	2. Minor	3. Moderate	4. Major	5. Catastrophic
5. Almost certain	Sea level rise	Hot weather			
4. Likely				Irregular season	
3. Possible					
2. Unlikely				Storm	
1. Rare					

Irregular weather is considered a "high" risk. The risk is the most severe that can be accepted as part of routine operations but adaptation solutions need to addressed quickly. Other climate change impacts are considered a "medium" risk and the risk can be expected to form part of routine operations but adaptation solutions need to be developed in the medium term and the risk monitored regularly.

Bac Lieu shrimp farmers perception of climate change type likelihood, consequence and thus risk is presented in

Table **9**. Overall climate changes of most concern were: high temperature extreme risk rating), too much rain (high risk rating) and Storms (high risk rating) Table 10. Farmers perception of risk varied between the commune groups with some communes perceiving extreme or high risk ratings for some other climate changes. However, there was consensus between communes in *Bạc Liêu* that high temperature had a extreme risk rating.

Table 9: Risk priority matrix of extreme events in *Bạc Liêu* province

Climate change impact	Commune	Consequence	Likelihood	Risk	Risk rank
1. High temperature	Vĩnh Hậu	4	5	20	1
	Gành Hào	4	5	20	1
	Long Điền Tây/Đông	4	5	20	1
	Average	4	5	**20**	**1**
2. Too much rain	Vĩnh Hậu	3	5	15	2
	Gành Hào	3	4	12	3
	Long Điền Tây/Đông	5	4	20	1
	Average	3.67	4.33	**15.67**	**3**
3. Sea level rise	Vĩnh Hậu	3	4	12	3
	Gành Hào	5	3	15	2
	Long Điền Tây/Đông	2	3	6	3
	Average	3.33	3.33	**11**	**4**
4. Storm	Vĩnh Hậu	5	4	20	1
	Gành Hào	5	4	20	1
	Long Điền Tây/Đông	5	2	10	2
	Average	5	3.33	**16.67**	**2**
5. Irregular season	Vĩnh Hậu	5	4	20	1
	Gành Hào	2	4	8	4
	Long Điền Tây/Đông	1	3	3	4
	Average	2.33	4	**10.33**	**5**

Table 10: Likelihood and consequence rating of climate change observed by farmer in *Bạc Liêu*

Likelihood	**Consequence**				
	1. Insignificant	2. Minor	3. Moderate	4. Major	5. Catastrophic
5. Almost certain				High temperature	
4. Likely		Irregular season	Too much rain		
3. Possible			Sea level rise		Storm
2. Unlikely					
1. Rare					

2.5. Adaptation measures presently used by farmers

In recent years, bad weather events such as high temperature, high rainfall, very hot weather for 3-4 days, irregular weather, sea level rise or storm occur more regularly and seriously in the world wide and the study areas. As a result, farmers have been adapting to these changes.

In *Cà Mau*, some suggested solutions to climate changes impacts include: maintaining better maintaining of pond water levels, planting trees on pond dyke to provide shade in response to hot weather; listening to radio weather warnings and harvesting shrimp prior to the arrival of severe storms; planting trees on pond dyke to stabilize it and make it more resistant to damage developing better crop calendars for storm impacts; reducing stocking density, culturing new species and practicing polyculture; using smaller ponds for the impacts related to irregular seasonal changes (Table 11).

Table 11: Farmers' solutions to climate change in *Cà Mau*

Climate change impact	**Solution**
1. Hot weather	- Deeper pond/canal and maintain suitable water level in the pond by pumping: water level >1.3m in ditch and about 0.8m in platform. - Farmers should exchange water more frequently. - Wider canal/ditch or more canal inside the pond - Plant tree around the farm/pond and water plants in the platform. - Farmers should establish the paddle wheel and mix water column. - Local authorities, especially local banks should help farmers in terms of finance/credit to strengthen farm infrastructure and buy necessary equipments. - Train for farmers on shrimp farming - Establish a network of local technical persons to support farmers on farm - Farmers try to fertilize the color water to prevent the sun through on bottom.
2. Sea level rise	- Strengthening farm/dyke: wider, harder and higher - Use net to prevent shrimp escape in emergency - Support from local banks (credit) to strengthen farm infrastructure (dyke, sluice gate, irrigation system, net) and loans for shrimp farming.
3. Rainfall	- Overflow - Use of lime - Aeration - Need support from local authorities: better weather forecasting and advises.
4. Storm and typhoon	- Dyke/farm/sluice gate improvement - Farmers should listening radio, monitoring frequently weather forecast and media. In the mean time, government also informs frequently and predicts or warns better forecast on the media. - Farmers can harvest shrimp before storm coming. - Farmers should plant tree around the dike of pond. - Scientists have to recommend for farmer about the suitable crop calendar, model culture or culture species for better practices. - Move to another place. - Need support from DARD and other local authorities to: strengthen dyke, provide weather forecasting exact and timing, provide credit or allocate budget to repair pond/farm - Local banks and provincial level have to help farmers to improve their pond to protect their shrimp farms from storms'

	impacts.
5. Irregular season	- Select good shrimp seed and well water treatment - Province and scientists have to plan/recommend about the suitable crop calendar for farmers. - Farmers should stock shrimp seed with less density. - Province and scientists should help farmer for culture species diversification or polyculture such as mud crab, fish etc. - Farmers need to divide many ponds in the same pond (smaller ponds). So they need help from local banks (credit). - Scientists and province have to train farmers to improve shrimp culture techniques. In addition, new technology also needs to research and apply in the context of climate change. - Farmers can apply probiotic to supplement in the feed content.

In *Bac Lieu*, shrimp farmers perception of climate changes and their impacts on their farming system are presented in Table 4. In the farmers opinion the climate change impacts can be categorized as in six key problems: water quality, shrimp disease, slow growth of shrimp, dyke damage, shrimp escape and sluice gate damage. The impacts were reported to be substantial in terms of production and economic loss. Suggested solutions to the six key climate change problems are presented in Table 12. Suggested solutions included: physical construction works improved canal and dyke systems, training in better management practices, and financial support. Farmers believe that the responsibility for such solutions rests with various government departments, universities and institutions, private companies, banks and the farmers themselves.

Table 12: Suggested solutions from farmers to climate change impacts in *Bạc Liêu*

Impact	**Solution**	**Responsible agent**
1. Water quality	Canal system improvement	DNRE
	Need training course on water quality	DARD; Aquaculture division
2. Disease	Manage seed quality and drug, chemical for fisheries	DARD; Aquaculture division
	Training on technical skills (how to use drug and chemical? How to build or repair the pond? Manage the water quality)	DARD; Aquaculture division
	Training and manage/control the disease and establish the centre for disease testing	DARD; Aquaculture division Universities; Institutes
3. Slow growth	More training courses on how to use chemical, drug, manage water quality, and other related to shrimp farming	Fisheries services Companies (private), Extension centre (govt)
	Training on how to use and manage chemical and drug, manage quality	DARD
	Training on manage water quality technique skills	DARD Universities; Institutes
4. Dike damage	Support loan for farmers (to improve the dike)	Agriculture and Rural Development Bank
	Improve dike system	DARD
5. Tidal flood	Support loan for farmers (to improve	Agriculture and Rural Development

leads to shrimp escape	the dike)	Bank
	Monitor the dike during the raining season	Farmers
6. Sluice gate damage	Improve sluice gate by farmers	Farmers
	Hire labors to repair /improve sluice gate	Agriculture and Rural Development Bank

DNRE: Department of Natural Resource and Environment of Vietnam
DARD: Department of Agriculture and Rural Development

Generally, shrimp farmers have been adapting to the impacts of climate changes and spend more money to deal with the climate changes. Therefore, they get less profit and have been impacted seriously on their income and likelihoods. They have a query that involved stakeholders need to establish appropriate solutions that summarized in Table 11 and Table 12 and implement them as soon as possible, while some solutions such as consolidate dykes and improve the farming systems must be conducted soon.

Chapter 3 – Stakeholder and Institutional Mapping and Analysis

This chapter is the result of the stakeholder meeting in the workshop organized on the 16th October 2009 and 27th March 2012 in *Cà Mau* province to consult with shrimp stakeholders to identify potential adaptation measures and discuss potential institutional and policy measures to climate change. Different stakeholders attended this workshop as follows:

- Farmers in *Cà Mau* and *Bạc Liêu* province. These provinces have a large proportion of land under shrimp farming.
- Local authorities in *Cà Mau* and *Bạc Liêu* at provincial, district and commune levels.
- University and institute

First, all stakeholders discussed the results from the Focus Group in the previous day. The separated group of farmers, scientists and local governors/officers focused on their roles in adaptation to potential climate changes in shrimp farming in *Cà Mau* and *Bạc Liêu* Provinces.

3.1. Stakeholder mapping and analysis

Stakeholder analysis is the identification of a sector's key stakeholders, an assessment of their interests, and influence and importance. Stakeholder analysis contributes to project design through the logical framework, and by helping to identify the most important stakeholders to target for implementing adaptation measures.

The identified stakeholder is any person or organization, who can be positively or negatively impacted by climate change in shrimp pond farming sector or had the significant influence on adaptations towards the problems.

Stakeholders are persons, groups or institutions involved in a sector. This definition of stakeholders includes both winners and losers, and those involved or excluded from decision-making processes.

Types of stakeholders are:

- Primary stakeholders: are those ultimately affected, either positively or negatively by shrimp production.
- Secondary stakeholders: are the 'upstream or downstream stakeholders or service providers', that is, persons or organizations who are indirectly affected by shrimp production.
- Key stakeholders: are those who can significantly influence, or are important to the success of the project in terms of the project's priority policy objectives and project purpose.

The results of stakeholder mapping including characterization and classification of key stakeholders and their tasks towards shrimp farming and climate change are presented in this section.

The stakeholders were classified by the expert judgment group into levels of importance and influence into grades (Table 13).

Table 13: Assessment grading scale

Assessment	Grading
Very low	1
Low	2
Moderate	3
High	4
Very high	5

A stakeholder is any person or organization, who can be positively or negatively impacted by, or Climate Change.

Table 14: Identification of stakeholders

Upstream[1]	Production	Downstream[2]
Shrimp post-larvae hatchery (breeding) producers	Caretaker	Shrimp brokers
Shrimp post-larvae nursery producers	Owner operator	Shrimp wholesalers
Shrimp post-larvae dealers	Private service providers	Shrimp processors
Feed manufacturers/dealers	Government service suppliers	Exporters
Fertilizer/chemical suppliers	Academic service suppliers	
	Private service providers	
	Government service suppliers	
	Academic service suppliers	

Stakeholder influence:

A stakeholder's degree of influence translates into the relative power they have over shrimp farming as well as the degree to which they can help desired changes to be implemented or blocked. In broad terms, a stakeholder's influence derives from their economic, social or political position, or their position in the hierarchy. Other forms of influence may be more informal (for example, personal connections to ruling politicians).

3.3. Stakeholder importance:

Importance is distinct from influence. There will often be stakeholders, especially unorganised primary stakeholders, upon which the project places great priority (eg. caretakers, owner operators, etc). Importance indicates the priority given to satisfying stakeholders' needs and interests through the project.

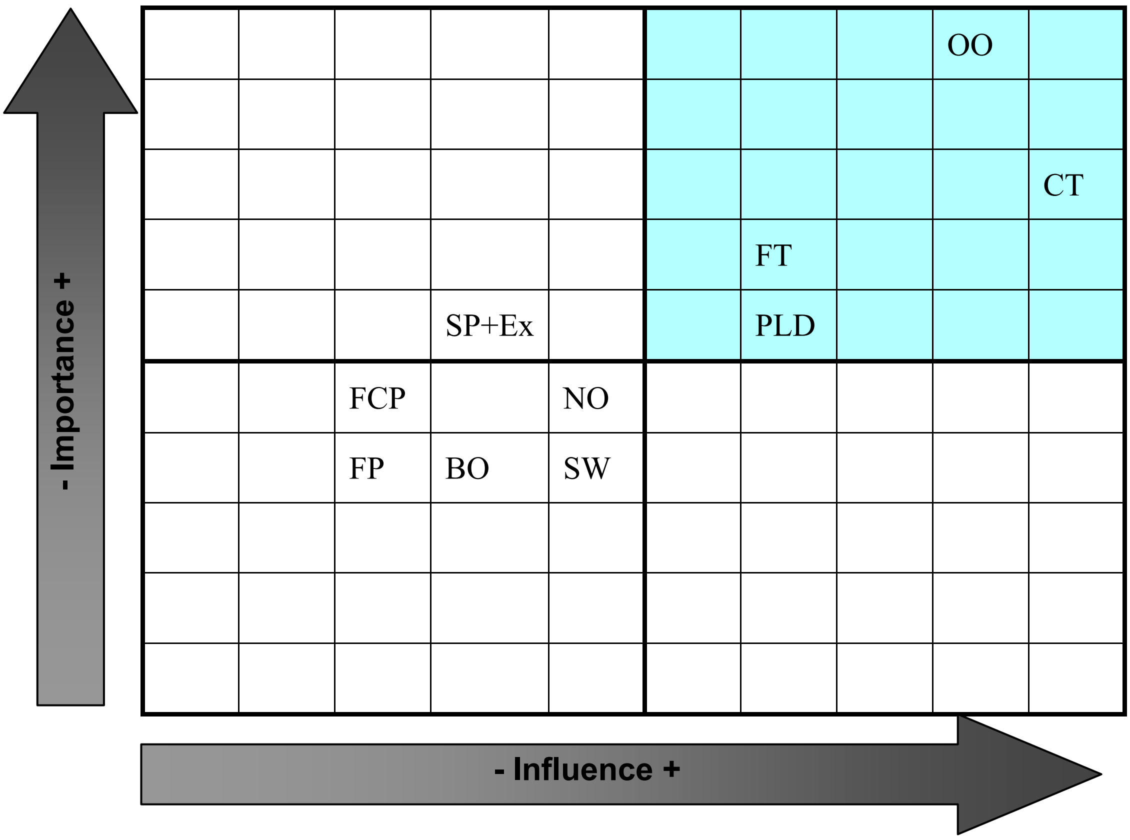
[1] *Upstream: covers the stakeholders that are producing goods that the shrimp producers need to produce the shrimp. Producers are the different types of farmer (owner, employee, landlord, etc) and service suppliers.*
[2] *Downstream: means all the stakeholders post harvest.*

Table 15: Assessment of stakeholder importance and influence

Stakeholder	Short name	Importance	Influence
Caretaker or manager	CT	4	5
Owner operator	OO	5	4.5
Breeding operator	BO	2	2
Nursery operator	NO	2.5	2.5
Post-larvae dealer	PLD	3	3.5
Shrimp wholesaler	SW	2	2.5
Feed producers/supplier	FP	2	1.5
Fertilizer/chemical supplier	FCP	2.5	1.5
Shrimp trader	FT	3.5	3.5
Shrimp processor	SP	3	2
Exporter	Ex	3	2

By combining influence and importance using a matrix diagram (Table 16), stakeholders can be classified into different groups, which will help identify key stakeholders to target.

Table 16: Stakeholder influence and importance



Stakeholders with low importance and low influence:

Stakeholders with low influence or importance to farm production may require limited adaptation measured developed, but are of low priority.

Stakeholders with high importance but low influence:

Stakeholders of high importance to tfarm production, but with low influence. This implies that they will require special initiatives if their interests are to be protected.

Stakeholders with low importance but high influence:

Stakeholders with high influence, who can therefore affect the implementation of adaptive measures, but have low interest in production. This implies that these stakeholders may be a source of significant risk, and they will need careful monitoring and management.

Stakeholders with high importance and high influence:

Stakeholders appearing to have a high degree of influence on farm production, who are also of high importance for its success. These are the key stakeholders to develop adaptation measures for.

3.2. Key stakeholders

Key stakeholders were therefore identified as:

- Owner operator
- Caretaker or manager
- Shrimp trader
- Post-larvae dealer

3.3. Institutional mapping and analysis

Institutions play a critical role in supporting or constraining people's capacity to adapt to climate change. In order to better understand which institutions are most important to people in the target communities, an institutional mapping exercise is useful.

The institutional analysis provides useful in identifying the institutions that should be engaged in the adaptation process, as well as potential allies and opponents in addressing vulnerability at the local level.

The institution is any organization, who can be positively or negatively impacted by climate change in milkfish pond farming sector or had the significant influence on adaptations towards the problems.

The Institutions were classified by the expert judgment group into levels of importance and influence into grades based on Table 13.

Institution influence:

Influence is the power institutions have over a sector - to control what decisions are made, facilitate its implementation, or exert influence which affects the sector negatively. Influence is perhaps best understood as the extent to which institutions are able to persuade or coerce others into making decisions, and following certain courses of action.

Power may derive from the nature of a institution, or their position in relation to other institutions (for example, line ministries which control budgets and other departments).

An institution's degree of influence translates into the relative power they have over Milkfish farming as well as the degree to which they can help desired changes to be implemented or funded or to which extent they can block changes. The Institution's influence derives from their political position and funds available.

Institution importance:

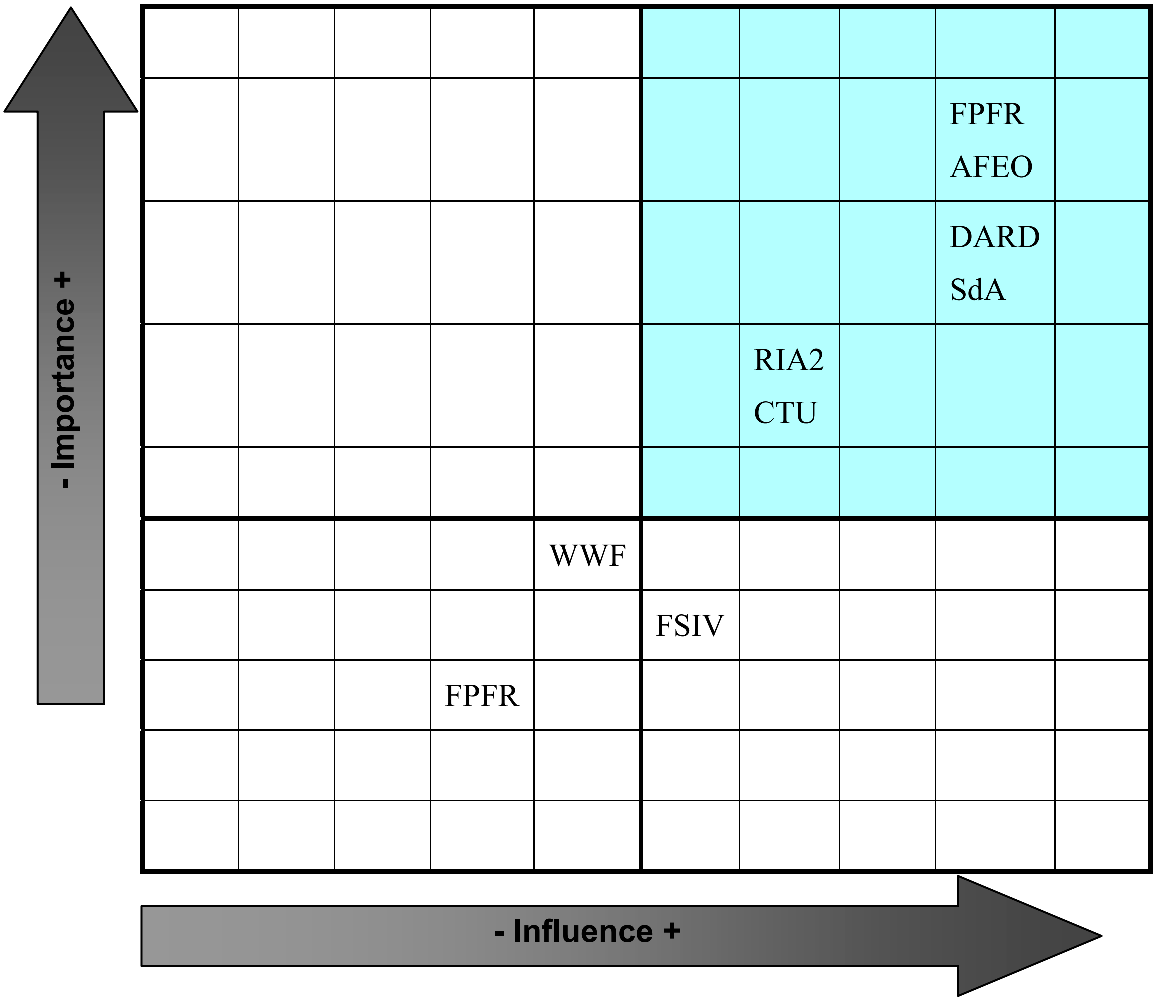
An institution's level of importance indicates the extent to which adaptations would be ineffective if they were not taken into account.

Table 17: Assessment of institution importance and influence

Institution	Short name	Importance	Influence
Department of Agriculture and Rural Development	DARD	4	4.5
Sub-department of Aquaculture	SdA	4	4.5
Sub-department of Fishing and Protection of Fisheries Resources	FPFR	1.5	2
Agriculture and Fisheries Extension Center (Province)	AFEC	4.5	4.5
Agriculture and Fisheries Extension Office (District)	AFEO	4.5	4.5
Forest Science Institute of Vietnam	FSIV	2	3
RIA2	RIA2	3.5	3.5
Can Tho university	CTU	3.5	3.5
WWF	WWF	2.5	2.5

Key stakeholders with high influence and importance for the implementation of adaptation measures and are likely to be the target institutions for recommendations, technical and policy briefs, and are potential partners in planning and implementation of adaptation measures. Conversely, key stakeholders with high influence, but with low importance to project success may be involved by being consulted or informed.

Table 18: Stakeholder influence and importance



Stakeholders first reviewed existing institutional and policy measures to adapt to climate change and then proposed measures that are need for the future (Table 19).

Table 19: Institutional and policy measures to adapt to climate change

Existing measures	
Consideration of available budget for the proposed research on climate change	Central government
Planning area for aquaculture and monitoring	DARD
Financial support (e.g., existing budget to help the affected farmers from risk such as climate change, loan from government).	DARD
Policy on mangrove planting for coastal protection, dike construction	DARD
Farmer association (subgroup cooperatives for shrimp culture in Bạc Liêu and Cà Mau)	Contact with extension station of the district (Cà Mau & Bạc Liêu) and commune (Cà Mau).
Measures Needed	
Provide and exchange information on climate change impacts to shrimp culture to DARD	-NACA -CTU

for policy development (i.e. shrimp stress/disease, water quality (pH, salinity, O2 temp. changes), slow growth, loss of production, dike damage)	-RIA2 -WWF -SIDA -DANIDA -NGOs
Give training on climate change impacts Training of the Trainers (TOTs) for DARD staff and extension to farmers	
Improve the policy on shrimp insurance (failed before). The insurance price should be based on the farm system	
Policy to maintain shrimp price	
Policy to establish more numbers of shrimp farm cooperatives	
Establish the shrimp disease inspection centre	- NGOs - Vietnamese government
Need policy to support the establishment of the centre to monitor the water quality in both shrimp ponds and natural water bodies	
Policy on monitoring the quality of chemicals, commercial feeds, and pro-biotics	

Existing measures included: consideration of available budget for research on climate change by the central government, aquaculture planning & monitoring and policy on mangrove planting by DARD, financial support from the Central government and implemented by DARD and farmer associations with contact with extension stations.

Measures that the group thought were needed in the future include: the provision and exchange of information and training of trainers on climate change to Vietnamese agencies such as DARD for policy development which was thought could be provided or funded by international organizations such as the NACA, and national organizations such as CTU and RIA2. Policy support was thought to be needed for maintaining shrimp prices, establishing shrimp cooperatives, establishing shrimp disease inspection centre and shrimp pond and natural water body water quality monitoring centre and on monitoring of the quality of chemicals, commercial feeds and probiotics.

The representatives from *Bạc Liêu, Cà Mau* DARD, fish and shrimp associations, federal science association, and extension workers in both provinces have already experienced the extreme weather events as the same farmers' and scientist's. The DARDs play important role in develop the adaptation measures for farmers. The DARDs could provide information and training to the farmer on the potential climate changes and their impacts. They need to fund basis research into the potential impacts of climate change so that they can have a scientific basis for setting priorities, forecasting potential changes, developing adaptation measures and mitigating aquaculture contribution to greenhouse gas. The DARDs are focusing the impacts of these events on degradation of water/environmental conditions for shrimp farming.

The central government has already recommended the provision of finance and credit to farmers and this is awaiting approval. The central and local governors need to consider the available budget for planning culture areas as well as certification the culture areas, while research institute, universities and NGOs are needed to conduct researches to help policy makers in planning culture areas and implementation regulations. Policy should be developed based on sound science. Moreover, there is a need to identify the responsibilities of provincial and district governments in conducting measurement/adaptation to potential climate changes. In addition, the government need to plant mangrove forests and construct the surrounding dikes in the coastal line to protect the communities from storms and sea level rise.

There is a need to revise the current strategy for aquaculture development, and incorporate new measures into National Policy and Regulations. They need to develop institutional capacity to address impacts from climate change. These can then be passed to provincial DARD and other agencies for implementation. There is a need for research fund and investment in infrastructure such as dykes and sluice gate maintenance, water supply sources, mangrove replanting and land use planning.

The centres for monitoring environment and diseases play important roles in early warning outbreak diseases and environmental impacts for shrimp farming. The Southern Hydrometeorology Centre, Ca Mau and Bac Lieu TV stations provide accurate information on weather forecast. Climate change scenarios need to be developed for predicting the potential climate changes in 20 years time. The changes may be different to those predicted so there needs to be adaptive management of the sector.

The extension workers need to be updated their knowledge and skills in transfer information not only techniques but also in policy as the culture areas will be certified or certification of the products need to be done in the near future. The training of trainer method is applied to help transferring techniques to farmers effective and on time. Present aquaculture production models are need to be reviewed as adaptation will require new shrimp farming models to be developed to cope with more rain and high temperature and irregular weather events. Training material needs to be revised and improved to include new materials for climate change.

Community and farmer associations need to understand with policy and strategy for sustainable development and adaptation measurement to climate changes. It needs cooperation among farmers to deal with the changes of climate in their community.

Therefore, the farmer associations need to be clustered and reorganized, then they can form organizations to be able to help themselves more effectively as the farmer organizations are the helpful places for farmer sharing their experiences and information on shrimp aquaculture activities as well as weather forecast and crop seasons. Other organizations that can be involved are the shrimp association, fishery association and women's union.

It needs to improve the net working among stakeholder in dealing with potential climate changes. They have to seat together for table discussion on impacts and adaptation to potential climate changes for each stakeholder partners. It also needs to have a link among all involved stakeholders such as policy makers, scientists, central and local governors, officers, food processing plants, hatcheries, seed suppliers, middle men and farmers. Workshops such this one organized by RIA 2 are a very useful tool for recognizing the climate change events and their impact, discussing problems and finding solutions.

Shrimp farming stakeholders suggested research and scientific measures that could help adapt shrimp farming to the climate change impacts that farmers identified as having impacts on their farming systems. As shrimp farmers identified, the key climate change impacts are hot weather, sea level rise, storm, irregular season and too much rain. Participants from Universities and institutes suggested following research and technology measures to adapt to climate change.

Measures suggested to adapt to hot weather and resulting water quality problems included: research on tree and mangrove planting, pond wetlands, polyculture, and demonstration farms to demonstrate pond engineering and design. Demonstration farms were considered most urgent. Agencies most appropriate to implement the measures according to stakeholders included: RIA2, CTU, Wetland research center Cà Mau and WWF.

Measures suggested to adapt to river / canal water level rise included: historic data and monitoring station on water level for early warming, identification of pollution types and sources that impact on aquaculture when flooding occurs and research on engineering aspects of pond design. Historic data and monitoring station on water level for early warming was considered most urgent. Agencies most appropriate to implement the adaptation measures according to stakeholders included: RIA2, CTU and the Aquaculture extension centre.

Measures suggested to adapt to storms included: information of sluice gate design, information of weather forecasts, research on coastal erosion and recovery and restoration of coastal areas. Research on coastal erosion recovery was considered most urgent. Agencies most appropriate to implement the measures according to stakeholders included: CSIRO, Cà Mau & Bạc Liêu Climate forecast center, Mangrove forest centre, Department of Agriculture and Rural Development (DARD), the Hydrology Institute RIA2 and CTU.

Research and scientific measures suggested to adapt to irregular season and associated water quality problems included: research on better quality seed and seed testing, research on environmentally tolerant aquatic aquaculture species and training course on water quality management. All of these topics were considered to be urgent. Agencies most appropriate to implement the measures included: RIA2 and CTU.

Measures suggested toadapt to too much rain and associated water quality and disease problems included: research on new technology, culture practices at different salinity levels, research about pond natural food chains. In summary, research and technology measures for each impact of climate change are showed in Table 20.

Table 20: Research and technology measures to adapt to climate change

Climate change	Impact	Solution	Responsible agent	Priority
1. Hot weather	-pH, salinity changes -High water temperature -Shrimp stress and disease - Toxic algae bloom	Study and research on tree plantation on the dike for suitable type of tree.	- Wetland research center Cà Mau - CTU - WWF	Important
		Set up the demonstration farms for engineering and pond design	- RIA2 - CTU	Urgent
		Research on polyculture techniques: stocking rate: milk fish (algae taken) and shrimp	- RIA2 - CTU	Important
		Research on plantation of wetland on platform of the pond (density)	- RIA2 - CTU	Important
		Research or study project on and to extend mangrove plantation		
2. Sea level rise	-Dike broken sluice gate damage	Need history data and monitoring station on water level for early	- Aquaculture extension centre	Urgent

	-Shrimp escape from ponds -Pollution from outside	warming		
		Need scientist to research on pollution sources and types	- RIA2 - CTU	Important
		Research for engineering and pond design	- RIA2 - CTU	Important
3. Storm	- Dike broken sluice gate damage - Shrimp escape from ponds - Mangrove destroy - Shrimp disease outbreak	Need information on dike and sluice gate design	- RIA2 - CTU	Important
		Information providing on weather forecast	- CSIRO - Cà Mau & Bạc Liêu Climate forecast center	Important
		Reforestation on the coastal area	- Mangrove forest centre - DARD	Important
		Research on coastal erosion recovery	- Hydrology Institute	Urgent
4. Irregular season change	- pH, salinity change - High water temperature - Shrimp stress and disease	Develop shrimp post larvae (PL) testing machine	- RIA2	Urgent
		Information providing and training course on water aquaculture management	- RIA2 - CTU	Urgent
		Research on seed production for high quality shrimp post larvae (PL)	- RIA2 - CTU	Urgent
		Research on diversify of aquatic species more tolerant in environment	- RIA2 - CTU	Urgent
5. Too much rain	- Shrimp stress and disease - pH, salinity changes - Low survival rate	Research on improved extensive shrimp culture	- RIA2 - CTU	Important
		Research and transfer new technology at hatchery to produce pathogen free post larvae (PL)	- RIA2 - CTU	Important
		Research on culture practices and techniques on different salinity level	- RIA2 - CTU	Important
		Research on natural food chain and nutrition in shrimp pond	- RIA2 - CTU	Important
		Improve brood stock	- Moina Company	Urgent

			- RIA2&1 - CTU	
		Training course for farmers on chemical and drug usage	- Extension center - RIA2 - CTU	Urgent
		Training for farmers on testing PL to select good quality.	- Extension center	Urgent
		Establishing farmer association/group	- Local farmer group	Important
		Guideline of culture techniques specific to each culture area	- RIA2 - CTU	Urgent

3.4. Key Institutions

Key Institutions were therefore identified as:

- Department of Agriculture and Rural Development (DARD)
- Sub-department of Aquaculture
- Agriculture and Fisheries Extension Center
- Agriculture and Fisheries Extension Office (district level)
- RIA2
- CTU

Cà Mau and Bạc Liêu are coastal provinces (Figure 6) with 533,200ha and 250,200ha respectively (19.3% of the Mekong Delta). Shrimp production in the two provinces contributed 50.4% to the Mekong Delta and 38.2% to the national production. Small-scale shrimp farming practices (extensive and improved extensive) is the largest production type by area and production in the Mekong Delta.

For example, most of all shrimp farming in Cà Mau is improved extensive (255,500 ha; 98,500 tons), while there are only about 2,000 ha, producing 10,000 tons for intensive farming. Similarity in Bạc Liêu, improved extensive farming is common (89,707 ha; 33,748 tons), there is 10,770 ha for intensive farming and contribute 27,218 tons to the total production (Figure 22). Improved extensive shrimp farmers practice a number of different systems including reliance on naturally occurring shrimp (*Penaeus indicus/merguiensis* + *Metapenaeus* spp.) post larvae or juveniles in the influent water, others stocking with hatchery reared black tiger shrimp (*Penaeus monodon*).

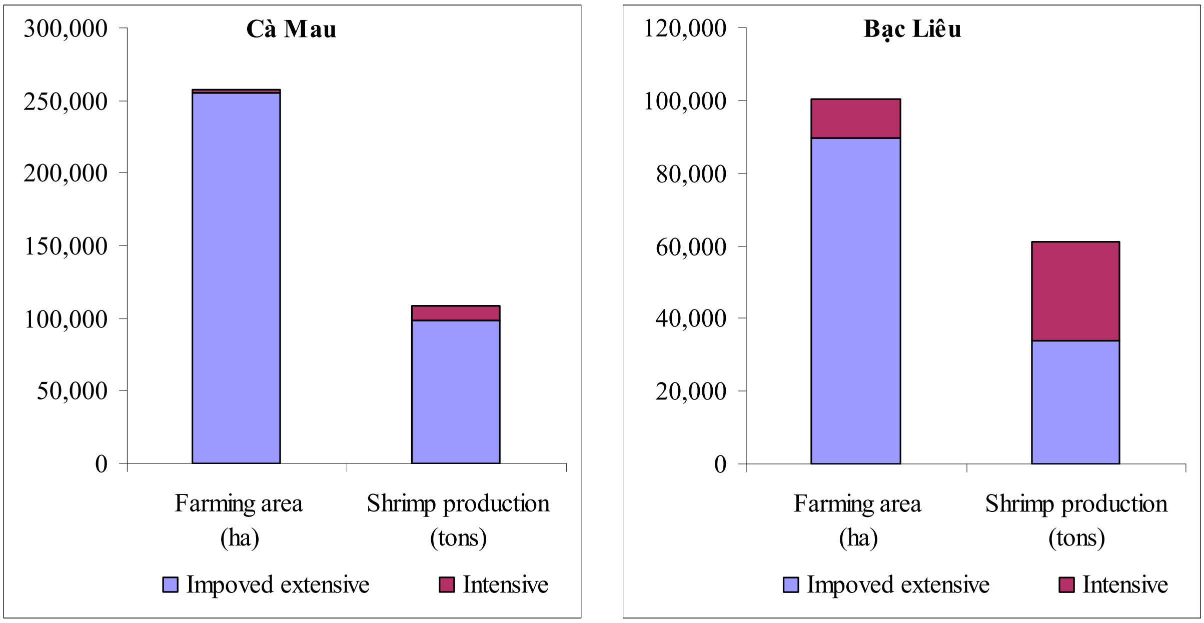


Figure 22: Farming area and shrimp production in Cà Mau and Bạc Liêu provinces in 2010

Small-scale shrimp farming with dominant improved extensive farming is considered to be the most vulnerable to climate change in recent years; farmers therefore are adaptive to changes in weather conditions. This report just focuses on the improved extensive farming with the aim at assessing farmers' perceptions and vulnerability to climate change and identifying adaptation actions and measures to help local farmers.

A questionnaire was designed by socio-economists with an aquaculture background. The revised questionnaire consisted of six parts including general information, socio-economic profile, farm information, farm production and economic information, climate change perception (types of climate change, climate change impacts on shrimp farming in terms of likelihood and consequence, adaptation, and adaptability), and climate change mitigation. The structured questionnaire was drafted and then revised after a pre-test. The questionnaire was then revised accordingly after the pre-tested survey (

Annex 4).

A total of 201 farmers was selected randomly and interviewed based on the questionnaire to map farmers' perceptions on impacts and adaptation as well as mitigation to climate change. In which, there are 100 farmers in *Cà Mau* province implemented by RIA2 and 101 farmers in *Bạc Liêu* province implemented by Can Tho University (CTU).

Data and information in the questionnaire was stored in a SPSS database. A number of statistical methods was used to test and analyze data in SPSS software such as descriptive statistics (mean, standard deviation, standard error of the mean, min, max, count value). Moreover, Chi-square and ANOVA tests were used to test the differences between means, a p-value with less than 0.05 was considered as statistically significant level.

4.1. Socio-Economic vulnerability indicators

Socio – economic characteristics of farmers and shrimp farming:

There were about 5 – 6 persons per household. In shrimp farming, there were about 2 – 3 persons per household, mainly male involved in farming (1 – 2 persons) while female less participates in shrimp farming (Table 21).

Table 21: Household member

Category	Province		Total
	Bạc Liêu	Cà Mau	
Number members	5.43	5.14	5.28
+ Male	2.78	2.51	2.65
+ Female	2.64	2.63	2.64
Number members involved in farming	2.08	2.40	2.24
+ Male	1.49	1.44	1.46
+ Female	0.62	0.95	0.79

Shrimp farming is the most important activities in both provinces in terms of income: 70.27% in Bạc Liêu and 82.27% in Cà Mau. Income from laboring contributes a relative high portion in both provinces (12%). Income from other activities such as agriculture, animal husbandry and salt making also contributes a proportion to the total income, particularly in Bạc Liêu (16.91%) (Figure 23).

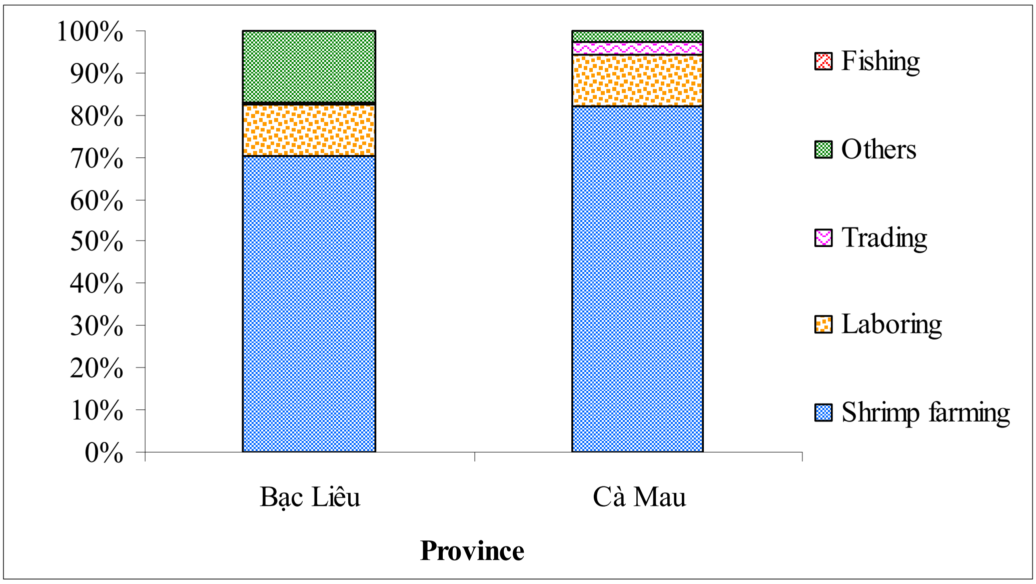


Figure 23: Percentage of household's income by different activities

Households in Cà Mau usually have 1 farm (1.01 farm) while in Bạc Liêu with 1.25 farm. However, farm in Cà Mau (2.36 ± 1.31 ha/farm) are usually larger than that in Bạc Liêu (1.77 ± 1.04). Number of farm and area per farm are significantly different between the two provinces. Considerably, there were 28 – 32% household farming with alternative rice crop: 1 shrimp crop in the dry season and 1 rice crop in the wet season per year (Table 22).

Table 22: Farm size

Category	Province		Total
	Bạc Liêu	Cà Mau	
+ Number of farm	1.25 ± 0.05 [a]	1.01 ± 0.01[b]	1.13
+ Farm size (Ha/farm)	1.52 ± 0.10 [a]	2.34 ± 0.13 [b]	1.93
+ Farm size (pond/farm)	1.31 ± 0.06 [a]	1.05 ± 0.02 [b]	1.18
+ Shrimp + rice (%)	31.68 [a]	28.00 [a]	29.85

Mean ±SE

Values in the same row with the same letter are not significant statistically (p>0.05)

Generally, there is a ditch around the farm/pond and inside the farm/pond. The platform usually are bare land or wild grass or can be used for rice cultivation in the wet season (Figure 24).

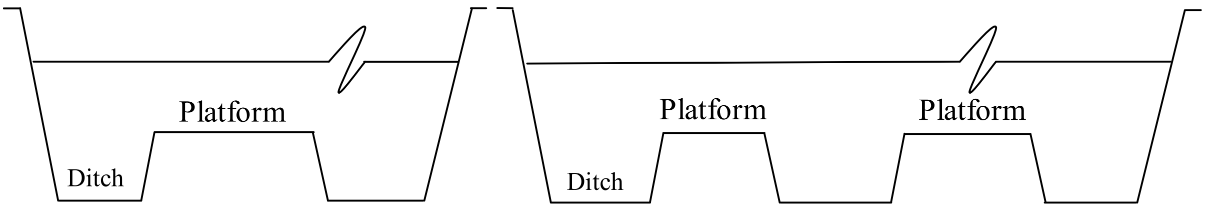


Figure 24: Side view diagram of pond structure

It can be seen that shrimp farming in both provinces plays an important role for food security and employment. Total household's income in Cà Mau (56.60 million VND/year) is higher than that in Bạc Liêu (50.11 million VND/year), but the different is not significant (p>0.05) (Table 23).

Table 23: Income sources of household

Income source	Province		Total
	Bạc Liêu	Cà Mau	
Shrimp farming (all farm)	36.24 ± 3.35[a]	46.57 ± 3.81[b]	41.40 ± 2.56
Loboring	6.18 ± 1.13 [a]	6.81 ± 1.35 [a]	6.49 ± 0.88
Trading	0.24 ± 0.13 [a]	1.83 ± 0.91 [a]	1.03 ± 0.46
Fishing	0	0.05 ± 0.05	0.02 ± 0.02
Others	8.27 ± 3.53 [a]	1.35 ± 0.63 [a]	4.83 ± 1.81
Total	50.11 ± 4.95 [a]	56.60 ± 4.08 [a]	53.34 ± 3.21

Mean ±SE

Unit: Million VNĐ/Household/Year (1USD ≈ 21,000VNĐ)

Values in the same row with the same letter are not significant statistically (p>0.05)

Total income in Bạc Liêu was correlated with their education, while income in Cà Mau is stable between education level (Figure 25). It is noted that almost all farmers belong primary (58,0%) and secondary (39.5%), there are only 3 cases with "no education" and 2 cases with "high school". It is likely that we can only compare between primary and secondary groups between the two provinces. In this case, there is no different between the two group in Cà Mau: 56.57 million VNĐ/HH/Year for "primary" and 56.74 million VNĐ/HH/Year for "secondary". Meanwhile farmers in Bạc Liêu have higher income when they are educated well (43.64 million VNĐ/HH/Year for "primary" and 67.42 million VNĐ/HH/Year for "secondary"). It is likely that farmers in Bạc Liêu province with better education can apply their knowledge to invest or do a business against climate change better than others.

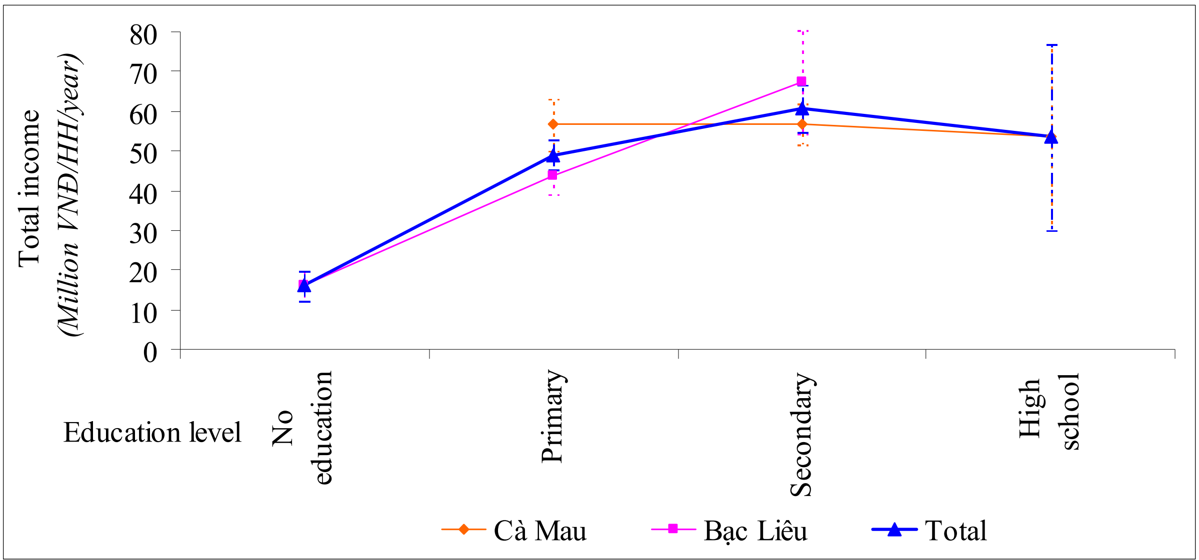


Figure 25: Relationship between total household's income and education level

Farmers' awareness about the climate change:

Shrimp farmers were asked whether they observed the occurrence of each given climate change events in recent years. The results show that most of farmers observed common climate change events such as tidal surge, irregular season, increase in temperature, increase in salinity, drought, heavy rain, and rapid temperature change (Table 24 & Figure 26).

Table 24: Shrimp farmer's perception of climate change

Climate change event	Bạc Liêu		Cà Mau		Total	
	Yes	No	Yes	No	Yes	No
Irregular season (%)	76.2	23.8	70.0	30.0	73.1	26.9
Temperature rapid change (%)	50.0	50.0	42.0	58.0	46.0	54.0
Temperature (high) (%)	75.0	25.0	69.0	31.0	72.0	28.0
Temperature (low) (%)	26.0	74.0	40.0	60.0	33.0	67.0
Typhoon/storm (%)	13.9	86.1	8.0	92.0	10.9	89.1
Heavy rain (%)	31.7	68.3	66.0	34.0	48.8	51.2
Flood from rain (%)	4.0	96.0	0	100.0	2.0	98.0
Drought (%)	30.6	69.4	67.0	33.0	49.0	51.0
Water salinity (increase) (%)	42.4	57.6	58.0	42.0	50.3	49.7
Water salinity (decline) (%)	5.1	94.9	27.0	73.0	16.1	83.9
Tidal surge/flood (%)	87.1	12.9	99.0	1.0	93.0	7.0
Others (%)	3.96	96.04	-	-	3.96	96.04

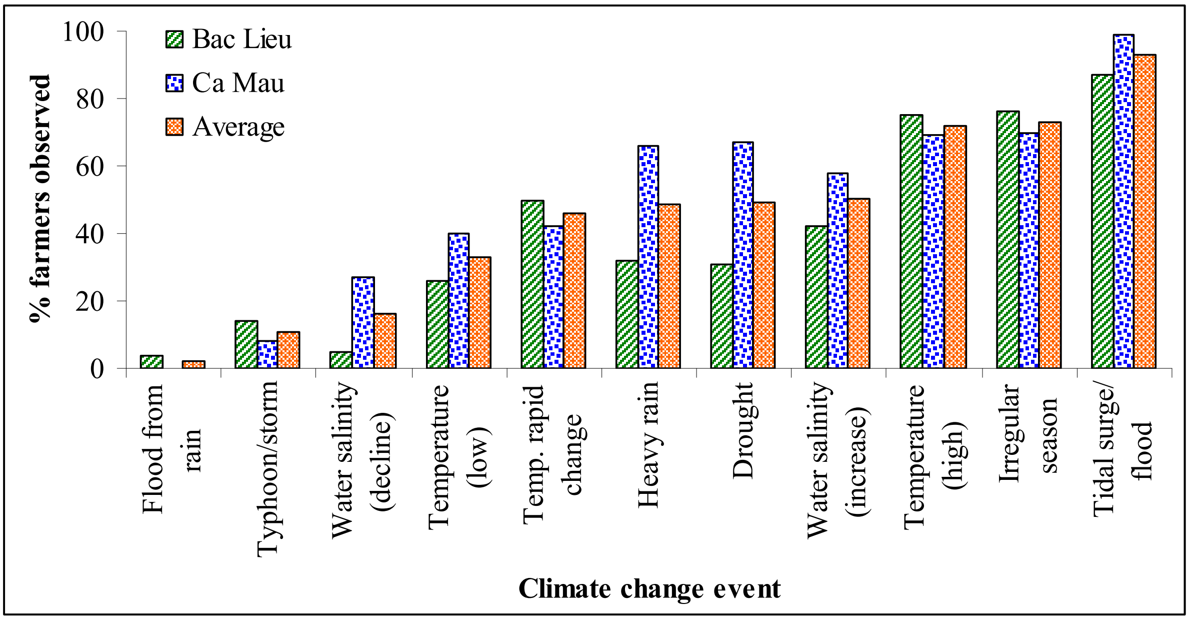


Figure 26: Climate change events observed

Most of farmers observed 3 – 7 climate change events (74% in Cà Mau and 83% in Bạc Liêu) (Figure 27).

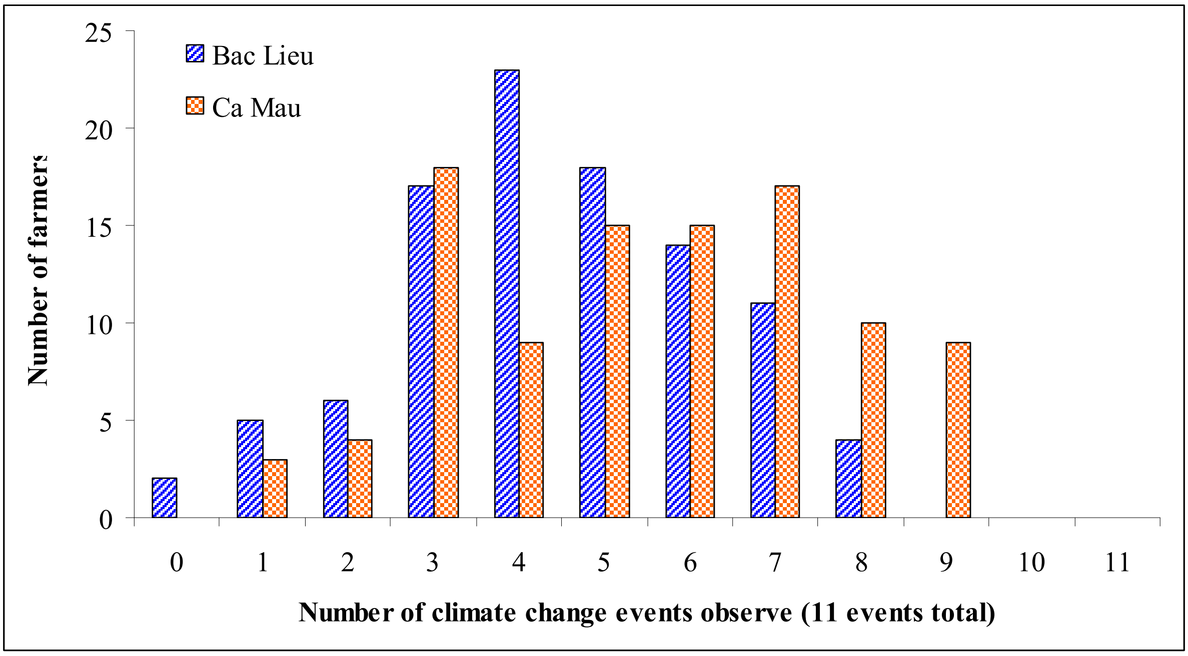


Figure 27: Frequency of observed climate change events

In order to test whether the perception of a given climate change event differs between two provinces, a Chi-square was used in this analysis. Although the two coastal provinces are located next to each other, there are only 4 climate change events (irregular season, temperature rapid change, temperature (high), and typhoon/storm) that are the same in farmers' perception between the two provinces. 7 events remaining are different between the two provinces (

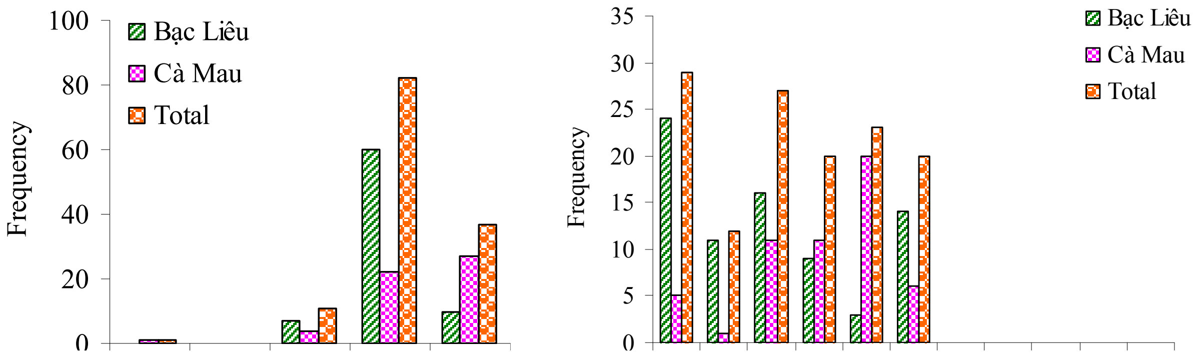
Table 25).

Table 25: Farmers' perception between Cà Mau and Bạc Liêu provinces

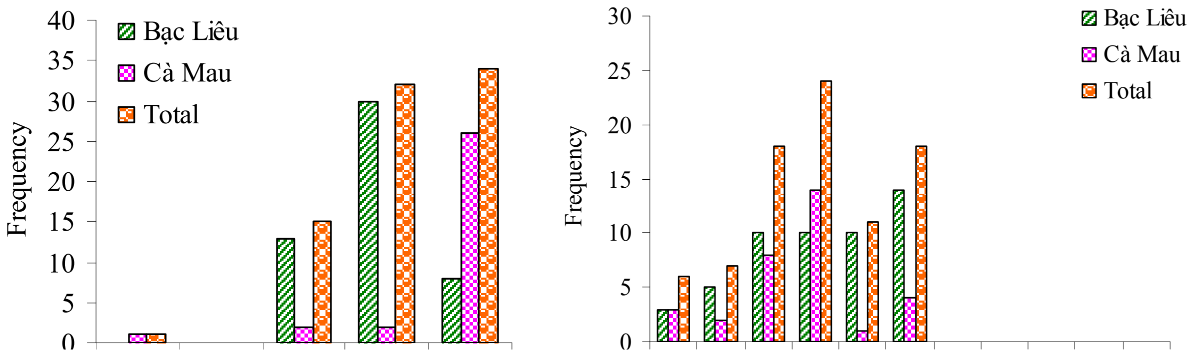
Climate change event	Chi-square value	p-value	Conclusion
Irregular season	0.995	0.319	Proportion are the **same** in two provinces
Temperature rapid change	1.288	0.256	Proportion are the **same** in two provinces
Temperature (high)	0.893	0.345	Proportion are the **same** in two provinces
Temperature (low)	4.432	0.035	Proportion are **different** in two provinces
Typhoon/storm	1.771	0.183	Proportion are the **same** in two provinces
Heavy rain	23.685	0.000	Proportion are **different** in two provinces
Flood from rain	4.041	0.044	Proportion are **different** in two provinces
Drought	26.225	0.000	Proportion are **different** in two provinces
Water salinity (increase)	4.828	0.028	Proportion are **different** in two provinces
Water salinity (decline)	17.761	0.000	Proportion are **different** in two provinces
Tidal surge/flood	10.928	0.001	Proportion are **different** in two provinces
All climate change events	22.218	0.008	Proportion are **different** in two provinces

Climate change likelihood and consequence:

Almost of all shrimp farmers believed that climate change events are "Likely" and "Almost certain" happening and influenced their farming systems. Almost of all impacts are negative, especially irregular season, high and rapid change in temperature. Considerably, some farmers stated that climate change can have positive impacts in shrimp farming such as water salinity increase and tidal surge (Figure 28).



Irregular season



Temperature rapid change

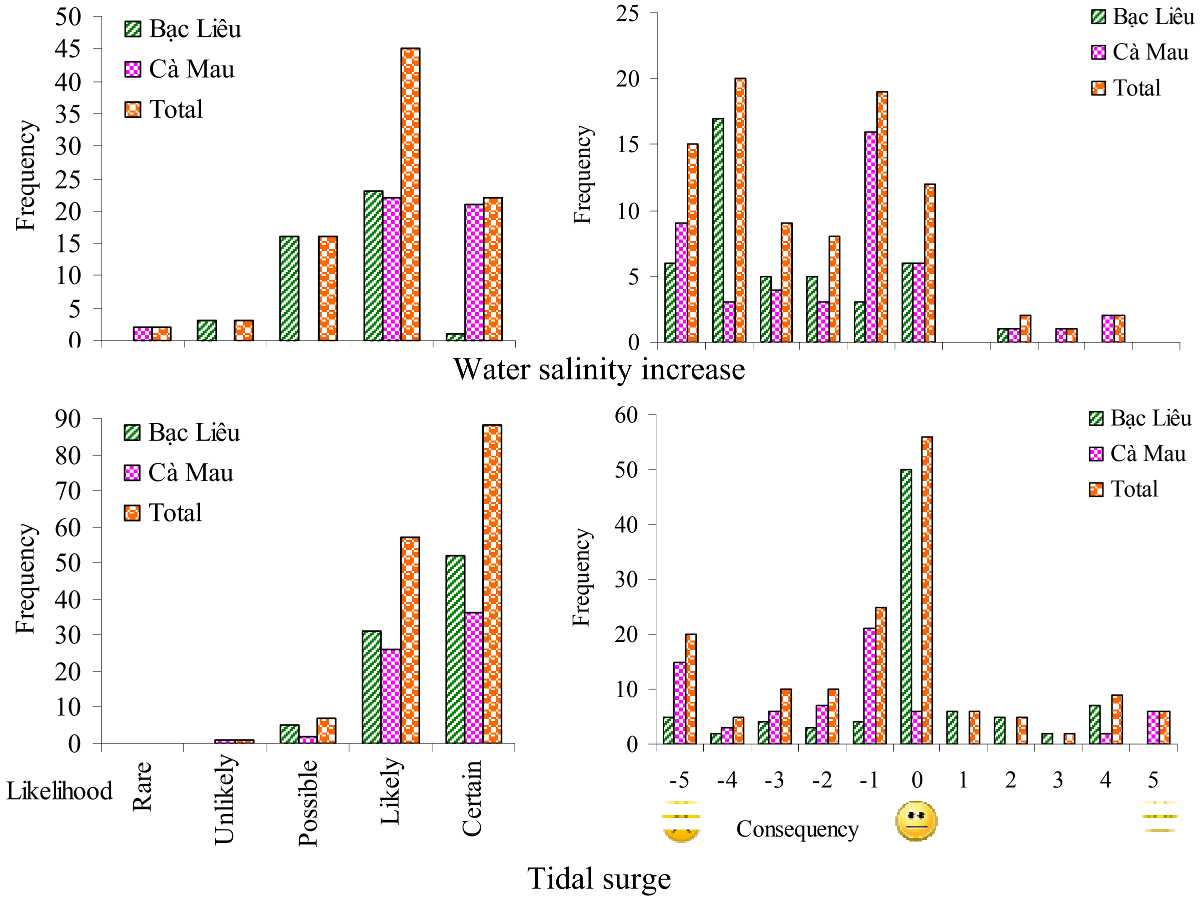


Figure 28: Impacts of typical climate change events on likelihood and consequence

(-5: catastrophic; -4:major negative; -3:moderate negative; -2:minor negative; -1:insignificant negative; 0:no consequence; 1:insignificant positive; 2:minor positive; 3:moderate positive; 4:major; 5:extremely positive)

In order to have an overall impact of climate change on shrimp farming in the Mekong Delta, all impacts of 11 of climate change events are combined for further analysis. The results show that 90.45% farmers observed climate change events in Cà Mau are "Likely" and "Almost certain" while there are 80.31% in Bạc Liêu. Especially more farmers in Cà Mau believed that climate change have been happened certainly (Figure 29).

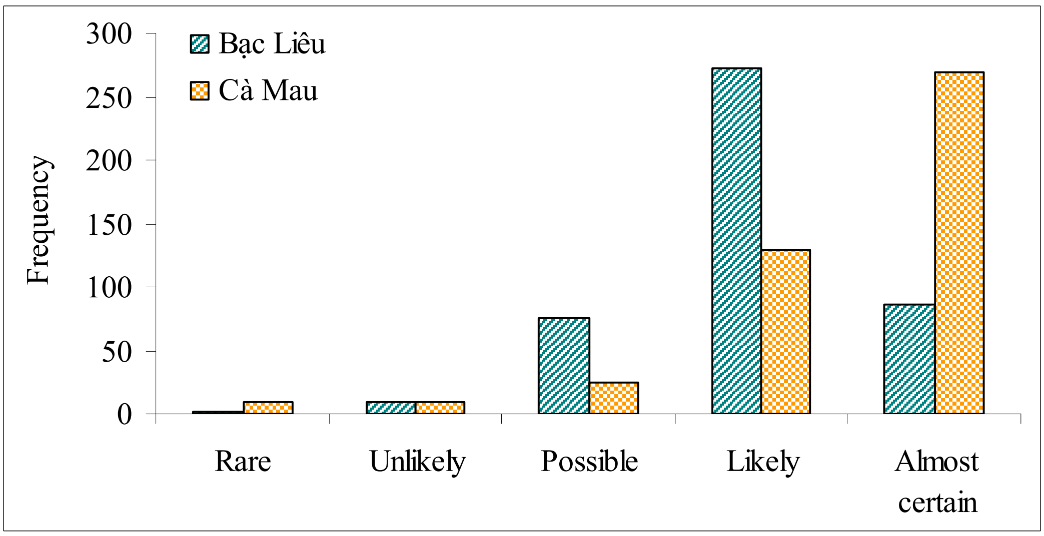


Figure 29: Impacts of all climate change events combined on likelihood

Farmers stated that most of climate change impacts have negative impacts (74.75%), 20,56% have no consequence and 4.69% have positive impacts. Considerably, farmers in Bạc Liêu believed that 30.36% have no impacts on their farming, while only 10.74% farmers in Cà Mau province (Figure 30).

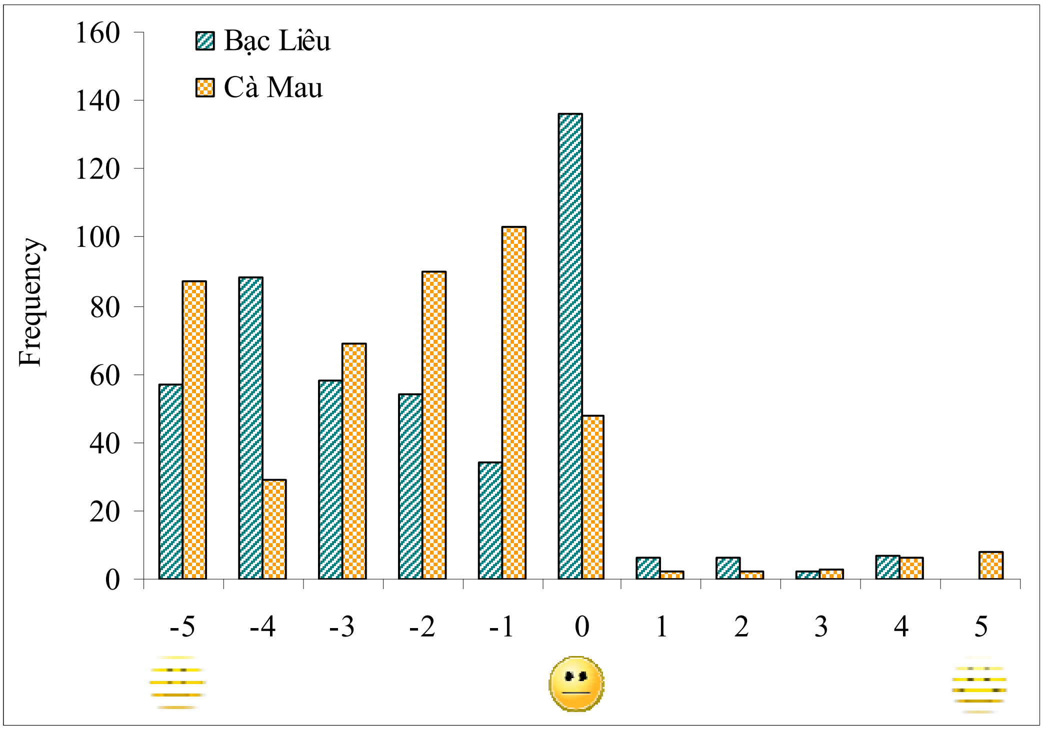


Figure 30: Impacts of all climate change events combined on consequence

(-5: catastrophic; -4:major negative; -3:moderate negative; -2:minor negative; -1:insignificant negative; 0:no consequence; 1:insignificant positive; 2:minor positive; 3:moderate positive; 4:major; 5:extremely positive)

Generally, extreme weather events and climate change has both negative and positive impacts. For example, salt water instruction has negative impacts on rice farming, in the same time it provides an opportunity to diversify their likelihoods into multi-cropping: rice crop in the wet season and shrimp in the dry season. Shrimp farming is more profitable than only rice farming.

Table 26 and Table 27 compare the farmers' perception of each climate change event between Cà Mau and Bạc Liêu provinces.

Table 26: Impacts of climate change on likelihood

Climate change event	Chi-square value	p-value	Conclusion
Irregular season	23.939	0.000	Proportion are **different** in two provinces
Temperature rapid change	40.635	0.000	Proportion are **different** in two provinces
Temperature (high)	47.733	0.000	Proportion are **different** in two provinces
Temperature (low)	31.562	0.000	Proportion are **different** in two provinces
Typhoon/storm	8.131	0.043	Proportion are **different** in two provinces
Heavy rain	46.678	0.000	Proportion are **different** in two provinces
Flood from rain	8.000	0.092	Proportion are the **same** in two provinces
Drought	24.017	0.000	Proportion are **different** in two provinces
Water salinity (increase)	39.179	0.000	Proportion are **different** in two provinces
Water salinity (decline)	17.532	0.001	Proportion are **different** in two provinces

Tidal surge/flood	2.226	0.527	Proportion are the **same** in two provinces

Table 27: Impacts of climate change on consequence

Climate change event	Chi-square value	p-value	Conclusion
Irregular season	34.704	0.000	Proportion are **different** in two provinces
Temperature rapid change	10.953	0.052	Proportion are the **same** in two provinces
Temperature (high)	39.967	0.000	Proportion are **different** in two provinces
Temperature (low)	9.543	0.216	Proportion are the **same** in two provinces
Typhoon/storm	12.245	0.015	Proportion are **different** in two provinces
Heavy rain	25.346	0.000	Proportion are **different** in two provinces
Flood from rain	8.000	0.046	Proportion are **different** in two provinces
Drought	19.528	0.003	Proportion are **different** in two provinces
Water salinity (increase)	22.872	0.004	Proportion are **different** in two provinces
Water salinity (decline)	8.851	0.264	Proportion are the **same** in two provinces
Tidal surge/flood	73.466	0.000	Proportion are **different** in two provinces

4.2. Climate change impacts on productivity

Characteristics of shrimp pond are almost the same between the two provinces, except the size of pond. Size pond in Cà Mau (2.21 ha/pond) is much bigger than that in Bạc Liêu (1.41 ha/pond) (Table 28).

Table 28: Pond size

Category	Province		Total
	Bạc Liêu	Cà Mau	
Pond size (ha/pond)	1.41	2.24	1.82
Height of dyke (m) *(bottom of ditch to the dyke top)*	1.63	1.63	1.63
Height of platform (m) *(bottom of ditch to the rice area)*	0.86	0.91	0.88
Water level *(from the bottom of the ditch)*	1.20	1.14	1.17

Farmers in Bạc Liêu stocked shrimp more than in Cà Mau province. In addition, farmers in both provinces also stock fingerlings and crabs in their farming systems. They were only 1 farmer in Bạc Liêu and 3 farmers in Cà Mau used commercial feed to shrimp (Table 29).

Table 29: Stocking and feeding

Category	Province		Total
	Bạc Liêu	Cà Mau	
Shrimp density *(PL15/m^2)*	2.84	1.26	2.05
Fish density *(ind/m^2)*	0.0024	0.0004	0.0014
Crab density *(ind/m^2)*	0.13	0.04	0.09
Used feed amount *(kg/ha/season)*	6.25 *(n=1)*	336.72 *(n=3)*	-

Most of shrimp owners educated at primary and secondary school and they have 9 – 12 shrimp farming experience. Parcicularly, about 27 – 33% farmers are association members (Table 30). Association members can be supported about the techniques and selling with high price.

Table 30: Characteristics of shrimp owners

Category	Province		Total
	Bạc Liêu	Cà Mau	
Age (head of household)	49.42 ± 11.86	47.06 ± 12.56	48.24 ± 12.24
Education level			
+ No education (%)	3.03 *(n= 3)*	0 *(n= 0)*	1.51 *(n= 3)*
+ Primary (%)	68.69 *(n= 68)*	48.00 *(n= 48)*	58.29 *(n= 116)*
+ Secondary (%)	28.28 *(n= 28)*	50.00 *(n= 50)*	39.20 *(n= 78)*
+ High (%)	0 *(n= 0)*	2.00 *(n= 2)*	1.01 *(n= 2)*
Shrimp farming experience (year)	9.11	11.69	10.40
Association member			
+ Yes (%)	32.63	27.00	29.74
+ No (%)	67.37	73.00	70.26

Shrimp farming productivity was correlated with education level, especially in Bạc Liêu province (127.43 kg/ha/season for Primary school vs 248.54 kg/ha/season for Secondary school), while productivity in Cà Mau is almost the same between the two group (Figure 31).

Education is also an important factor impacting the production. It is likely that farmers produce higher production when they had higher education level. It applies that farmers with higher education level can adapt better in shrimp farming.

In addition, farmers in Cà Mau as association member produce higher production (151.28 kg/ha/season with association member; 126.23 kg/ha/season with non-member). However, farmers in Bạc Liêu with non-association member produced higher production (131.27 kg/ha/season with association member vs 182.33 kg/ha/season with non-member). There is likely another factor influencing the production or farmers in Bạc Liêu may be limited in support from the associations.

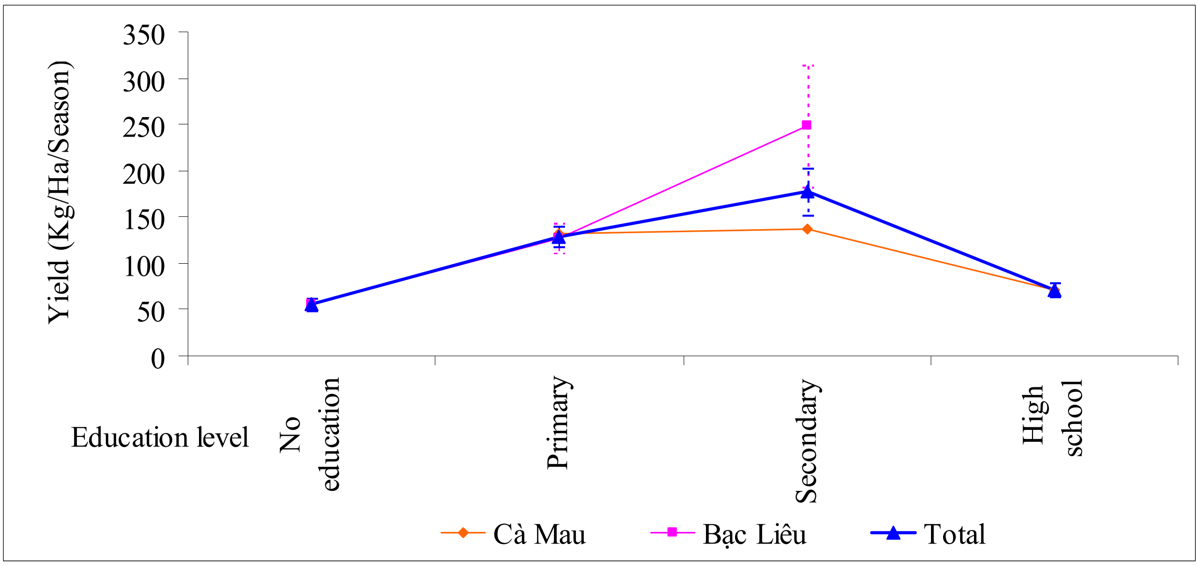


Figure 31: Relationship between shrimp farming productivity and education level

In terms of production, shrimp contributed the largest proportion to the total production (% in Cà Mau; % in Bạc Liêu). Considerably crab production also contributed a considerable percentage in the total production (% in Cà Mau; % in Bạc Liêu). Fish is unlikely important for local farmers (Figure 32) as farmers stocked fingerlings with a relative low density (Table 29).

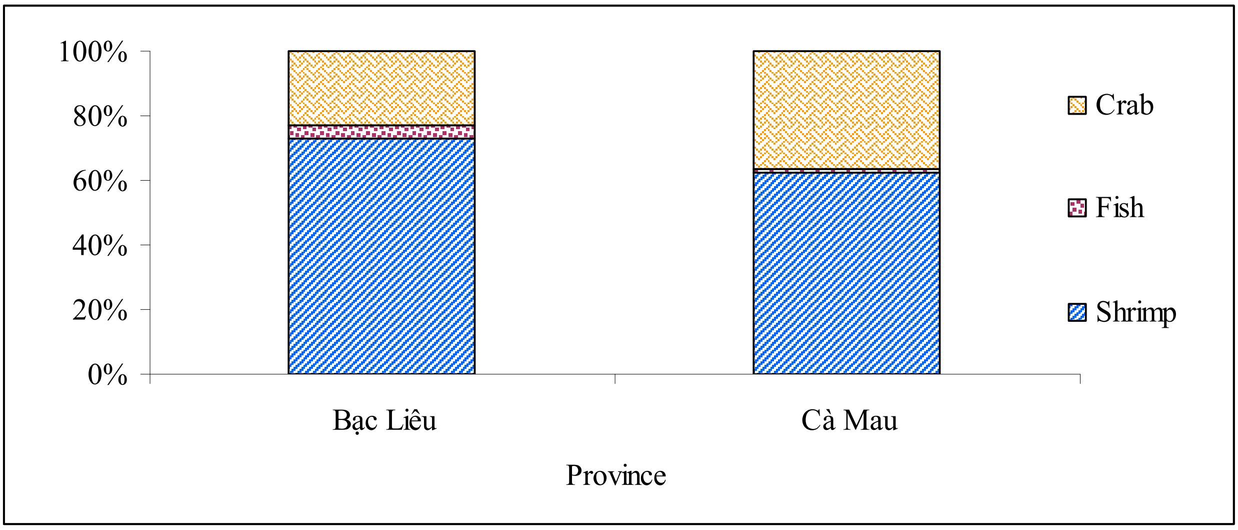


Figure 32: Percentage of production type

Productivity of shrimp farming is about 149.36 kg/ha/season (133.00 kg/ha/season in Cà Mau and 159.60 kg/ha/season in Bạc Liêu). In which, 107.74 kg of shrimp, 43.99 kg of crab and 2.32 kg of fish (Table 31).

Table 31: Shrimp farming yield between two provinces

Category	Province		Total
	Bạc Liêu	Cà Mau	
Shrimp (kg/ha/season)	132.67	84.32	107.74
Fish (kg/ha/season)	3.08	1.55	2.32
Crab (kg/ha/season)	37.09	50.68	43.99
Total (kg/ha/season)	159.60±22.62[a]	133.00±6.82[a]	146.36

It is hypothesized that farmers observed climate change could impact their shrimp farming. For three climate change events: Irregular season, Temperature raid change and Temperature (high), farmers not observed the events have much higher production in both provinces (Table 32).

Table 32: Impact of climate change on yield (kg/ha/season)

Climate change event	Bạc Liêu		Cà Mau		Total	
	Yes	No	Yes	No	Yes	No
Irregular season	**151.97**	**184.06**	**127.69**	**145.38**	**140.41**	**162.57**
Temperature rapid change	**147.71**	**173.48**	**125.30**	**138.57**	**137.48**	**154.73**
Temperature (high)	**127.88**	**258.73**	**129.45**	**140.89**	**128.63**	**193.50**
Temperature (low)	210.52	143.16	134.13	132.24	164.22	138.27
Typhoon/storm	348.92	129.13	124.48	133.74	267.30	131.50
Heavy rain	188.57	146.16	133.96	131.13	151.79	141.20
Flood from rain	217.81	157.20	-	133.00	217.81	144.91
Drought	143.08	132.20	139.30	120.20	140.47	128.28
Water salinity (increase)	142.69	169.62	135.06	130.15	138.27	152.88
Water salinity (decline)	148.54	162.15	142.13	129.62	143.13	147.93
Tidal surge/flood	170.38	86.60	131.82	250.00	149.96	98.27

Notes: yield including shrimp, fish and crab

Correlation analysis shows that there is negative relationship between productivity of shrimp farming and farm/pond size in both provinces (Table 33). It applies that smaller ponds can be more effective. It is likely that farmers with smaller farm/pond can manage their system better in term of productivity.

Table 33: Correlation (r) between productivity (kg/ha/season) and different variables

Category	Cà Mau		Bạc Liêu	
	r	p	r	p
Household and farm characteristics				
Total member in household	-0.115	0.254	-0.058	0.427
# members involved in farming	-0.043	0.674	-0.001	0.993
Income: shrimp farming (VND/year)	0.129	0.202	**0.379**	**0.000**
Total income (VND/year)	0.085	0.403	0.174	0.082
# of shrimp farm	-0.125	0.214	-0.081	0.421
Farm size (ha)	**-0.375**	**0.000**	**-0.251**	**0.011**
Farm size (ha/farm)	**-0.358**	**0.000**	**-0.214**	**0.032**
Pond size (ha/pond)	**-0.379**	**0.000**	**-0.305**	**0.000**
Height of dyke (m)	-0.168	0.096	0.054	0.589
Shrimp farming experience (year)	-0.068	0.499	0.098	0.334
Farm year old (# year)	-0.068	0.499	0.125	0.211
Water level	-0.122	0.227	0.146	0.146
Stocking				
Shrimp stocking (PL/m^2)	**0.248**	**0.013**	**0.311**	**0.002**
Fish stocking (fingerling/m^2)	0.045	0.655	-0.035	0.729
Crab stocking (crab/m^2)	0.084	0.408	0.052	0.604
Feed amount (kg/season)	0.044	0.666	0.094	0.348
Costs				
Sediment removal (VND/ha)	**0.374**	**0.000**	**0.410**	**0.000**

Lime + chemical + drug (VND/ha/season)	-0.005	0.964	**0.305**	**0.002**
Feed (VND/ha/season)	0.044	0.666	0.134	0.182
Labor (VND/ha/season)	-0.138	0.171	-0.006	0.953
Fuel + electricity (VND/ha/season)	0.058	0.565	-0.001	0.989
Dyke and sluice gate repairing (VND/ha)	-0.007	0.943	-0.040	0.693
Land tax and lease (VND/ha/year)	-0.130	0.199	-	-
Loan (VND/year)	-0.123	0.222	-0.070	0.487

Stocking density of post larvae (shrimp) and sediment removal cost have positive relationship with productivity. Sediment removal can help to improve the pond environment and also to attract wild shrimp into the pond. The fact shows that new farms established are usually produce more shrimp and usually no occurrence of disease.

4.3. Climate change impacts on economic viability

Farmers in Cà Mau province (3,871,033 VND/ha/season) had fewer amounts of costs than in Bạc Liêu (5,163,798 VND/ha/season) (Table 34).

Table 34: Costs in shrimp farming

Category	Province		Total
	Bạc Liêu	Cà Mau	
Cost (VND/household/season)	6,378,168	8,292,519	7,330,581
Cost (VND /ha/season)	5,163,798	3,871,033	4,520,631
Profit (VND/ha/season)	8,033,656	17,761,266	12,873,263

Most of costs were sediment removal (Table 35): 32.37% in Bạc Liêu and 60.51% in Cà Mau. Shrimp and crab seed costs were also important. Especially, loan was very common in both province: 31.68% in Bạc Liêu and 43.00% in Cà Mau. Each household loan about 28.51 million VND on the average from the local banks or from their relatives for shrimp farming, and they have to pay about 10% per year. Farmers in Cà Mau (31.58 million VND) have a loan bigger than in Bạc Liêu (24.40 million VND), therefore they have to pay more for the loan. This indicates that farmers in both provinces are relatively poor and they do need the support from the local authorities to invest in shrimp farming.

Table 35: Percentage of costs in shrimp farming

Cost category	Province		Total
	Bạc Liêu	Cà Mau	
Sediment removal	32.37	60.51	48.60
Seed (crab)	19.47	7.29	12.45
Loan	17.39	7.27	11.56
Seed (shrimp)	12.97	9.89	11.19
Land lease	-	5.91	3.41
Labor in pond preparation	6.60	0.13	2.87
Sluice repairing	0.05	4.91	2.85
Dyke repairing	4.27	1.00	2.39
Feed	3.16	0.07	1.38
Lime	0.96	1.21	1.10
Seed (fish)	0.06	1.28	0.76
Fertilizer	1.21	0.20	0.63
Other chemicals	0.76	0.02	0.33

Drug	0.43	-	0.18
Fuel	0.04	0.20	0.13
Electricity	0.23	-	0.10
Land tax	-	0.07	0.04
Labor in pond operation	-	0.05	0.03
Others	0.05	-	0.02
Total	**100.00**	**100.00**	**100.00**

There was only farmers in Cà Mau with loss profit (0.81 million VND), while 23/101 farmers in Bạc Liêu lost profit with an average of 6.68 million VND per farmers.

In addition, there was a closed relationship between profit and level of education (Figure 33). Farmers with higher education tend to get more profit, especially in Bạc Liêu province.

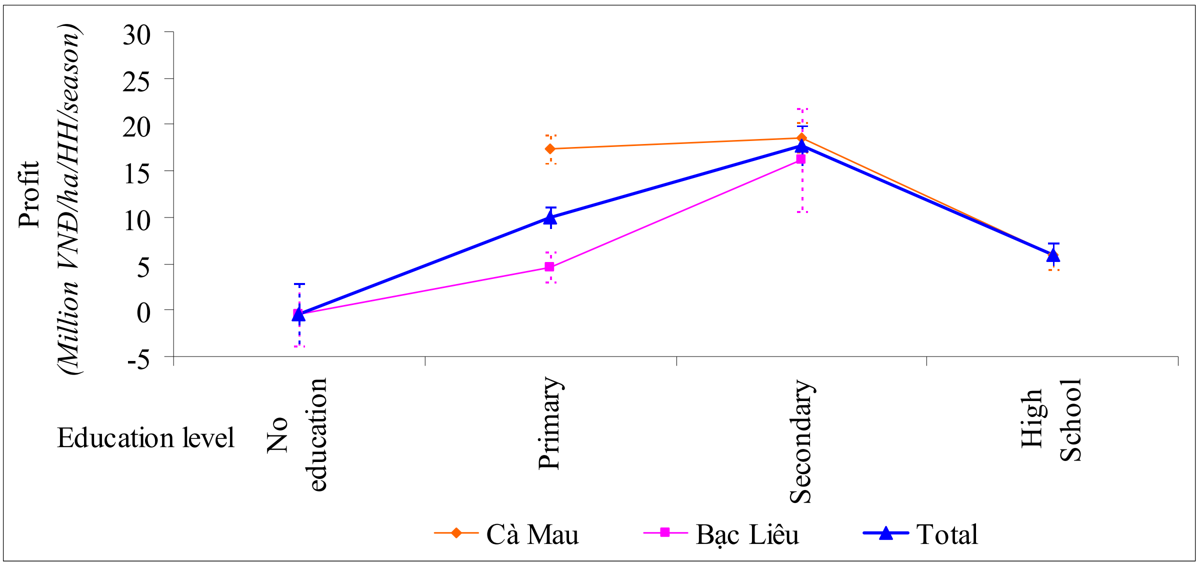


Figure 33: Relationship between profit and education level

Impacts of climate change on shrimp farming in Cà Mau are likely more obvious than in Bạc Liêu in terms of profit. For example, profit of farmers in Cà Mau who observed climate change events was much lower than farmers who did not observe the events. It indicates that climate change has negative impacts on their farming in Cà Mau. Impacts of "Temperature (high); Water salinity (increase); Water salinity (decline)" events in Bạc Liêu are similar to Cà Mau, however farmers' profit who observed the remaining events were lower than farmers who did not observed (Table 36). It implies that farmers in Bạc Liêu are likely better adaptive to climate change.

Table 36: Impact of climate change on profit (Million VND/ha/season)

Climate change event	**Bạc Liêu**		**Cà Mau**		**Total**	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**
Irregular season	8.19	7.52	16.92	19.74	12.34	14.31
Temperature rapid change	8.20	8.35	15.74	19.23	11.54	14.19
Temperature (high)	5.44	16.42	16.55	20.45	10.77	18.65
Temperature (low)	11.90	6.72	16.89	18.34	14.92	11.92
Typhoon/storm	24.18	5.44	14.35	18.06	20.60	11.92
Heavy rain	12.09	6.18	17.97	17.36	16.05	9.85
Flood from rain	19.36	7.57	-	17.76	19.36	12.74

Drought	7.55	5.45	17.58	18.12	14.48	9.59
Water salinity (increase)	4.53	10.89	17.98	17.46	12.33	13.68
Water salinity (decline)	5.93	8.33	18.12	17.63	16.22	12.40
Tidal surge/flood	8.71	3.43	17.57	36.60	13.40	5.80

Correlation analysis shows that there is positive relationship between profit of shrimp farming and income in both provinces (

Table 37). Moreover, profit tends to decline when the size of pond/farm is bigger ($p>0.05$). Therefore, farmers should establish pond smaller and they can manage and take care better and have more profit.

Table 37: Correlation (r) between profit (VND/ha/season) and different variables

Category	Cà Mau		Bạc Liêu	
	r	p	r	p
Household and farm characteristics				
Total member in household	-0.028	0.782	-0.038	0.704
# members involed in farming	0.011	0.910	-0.025	0.802
Income: shrimp farming (VND/year)	**0.303**	**0.002**	**0.543**	**0.000**
Total income (VND/year)	**0.258**	**0.010**	**0.275**	**0.005**
# of shrimp farm	-0.106	0.295	-0.118	0.244
Farm size (ha)	-0.153	0.129	-0.065	0.518
Farm size (ha/farm)	-0.137	0.175	0.000	0.998
Pond size (ha/pond)	-0.155	0.125	-0.123	0.219
Height of dyke (m)	-0.230	0.022	0.082	0.412
Shrim farming experience (year)	-0.140	0.165	0.122	0.226
Farm year old (# year)	-0.140	0.165	0.104	0.299
Water level	-0.056	0.580	0.155	0.123
Stocking				
Shrimp stocking (PL/m^2)	0.148	0.141	0.169	0.094
Fish stocking ($fingerling/m^2$)	0.005	0.963	-0.001	0.992
Crab stocking ($crab/m^2$)	0.131	0.196	-0.301	0.002
Feed amount (kg/season)	0.074	0.466	0.028	0.782
Costs				
Sediment removal (VND/ha)	0.135	0.179	0.047	0.642
Lime + chemical + drug (VND/ha/season)	-0.045	0.658	0.023	0.818
Feed (VND/ha/season)	0.074	0.466	0.040	0.693
Labor (VND/ha/season)	-0.210	0.036	-0.173	0.084
Fuel + electricity (VND/ha/season)	0.032	0.751	-0.031	0.755
Dyke and sluice gate reparing (VND/ha)	0.094	0.354	-0.066	0.512
Land tax and lease (VND/ha/year)	-0.148	0.142	-	-
Loan (VND/year)	-0.126	0.213	-0.147	0.144

Moreover, loan was common in both province (31.68% in Bạc Liêu & 43.00% in Cà Mau). Correlation analysis also found that there was a negative relationship between loan and profit, but it is not significant in both provinces.

4.4. Production function estimation

The Applied Aquaculture Production Function (AAPF) estimation along with Major Operating Cost Structure (MOCS) has been investigated for these major aquaculture parameters in all aqua-farm activities. The AAPF is basically drawn from production function estimation through its monetary value by an application of duality theory. Initially, a general production function can be presented as:

$$Ouput = f(Input_j) \qquad (1)$$

The output (O) generally represents the obtained amount of production from all inputs "j" utilized within the production period. These inputs can be further categorized into 3 main groups; Physical Aspects of the Production System (PA), Production Management Aspects (PMA) and Production Input Aspects (PIA) (See Table 38), respectively.

A modified production structure through an assistance of cost structure based on the duality theory can be demonstrated as:

$$O_i * PO_i = f(PA_{ij}, PMA_{ij}, PIA_{ij} * P_{ij}) \qquad (2)$$

For converting PIA into monetary unit for each "i" (i = individual farm) and "j" (j = type of input), the PIA can be multiplied with the price per unit (P_{ij}). The Output (O_i) can also be measured in monetary unit (Perfectly competitive market and rational maximizer assumptions have been applied) by multiplying a price of output (PO_i).

In order to capture an impact of climate change as an external factor unavoidably incorporated into the shrimp production system, the Climate Change Impact(s) (CCI) by "i" type can be added into the AAPF model as:

$$O_i * PO_i = f(PA_{ij}, PMA_{ij}, PIA_{ij} * P_{ij}, CCI_{ij}) \qquad (3)$$

Table 38: Example list of variables

PA Variable	PMA Variable	PIA Variable	CCI Variable
• Total water area of the farm Pond (ha) • Water area (ha) • Pond depth (ha) • Water depth (m) • Dyke Height (m) • Pond age (m) • Etc.	• Owner's age (year) • Aquaculture experience (year) • Education (year) • Training course attended (time) • Income from all household activities (% or annual monetary value) compared to an aquaculture income • Land ownership (dummy) • Number of Farm(s) owned (farm) • Total number of pond(s) in a selected survey (farm) • Etc.	• Shrimp stock density (fry/ha) or number of fry released per pond (fry/pond) • Shrimp stock cost (value/pond) • Shrimp stock size (size) • Homemade or commercial feed used amount (kg/pond) • Total homemade or commercial feed cost (value/pond) • Total chemical amount used (weight/pond) • Total chemical cost (value/pond) • Total Drug amount used (weight/pond) • Total Drug cost (value/pond) • Total electricity/fuel cost (value/pond) • Total amount of temporary or permanent labor used (day) • Total temporary or permanent labor cost (value) • Total sediment removal cost (value) • Total pond preparation cost (value) • Etc.	• Climate change impact – Flood (yes/no) • Climate change impact – Irregular weather (yes/no) • Climate change impact – Heavy rain/storm (yes/no) • Climate change impact – Temperature fluctuation (yes/no) • Climate change impact – Salinity (yes/no) • Climate change impact – Others (yes/no) • Climate change gradual impact – Temperature (yes/no) • Climate change gradual impact – Early or heavy rain (yes/no) • Climate change gradual impact – Change in season timing (yes/no) • Climate change gradual impact – Water pollution (yes/no) • Climate change gradual impact – River/ Canal level rise (yes/no) • Climate change gradual impact – Wind change (yes/no) • Climate change gradual impact – Others (yes/no)

Source: Type of each input collected through the project survey in 2009. All input values are provided by crop

The general form of AAPF (3) is given by the following equation (4):

$$O_i * PO_i = b_0 + \sum_i b_{ij}^{PA} PA_{ij} + \sum_i b_{ij}^{PMA} PMA_{ij} + \sum_i b_{ij}^{PIA} PIA_{ij} P_{ij} + \sum_i b_{ij}^{CCI} CCI_{ij} \qquad (4)$$

In addition to statistically selected inputs in AAPF estimation, an adjusted-R2 or coefficient of determination commonly provides a goodness of fit test. In other words, based on AAPF setting, it can measure how well each individual's revenue explained by each individual's direct and indirect investment.

According to technical efficiency, the coefficients obtained from (4) can be performed an elasticity calculation to compare a relative importance (ranking) of independent variables as follows:

$$E_{O/PA_{ij}} = b_{ij}^{PA} \frac{PA_{ij}}{O_i * PO_i} \qquad (5)$$

$$E_{O/PMA_{ij}} = b_{ij}^{PMA} \frac{PMA_{ij}}{O_i * PO_i} \qquad (6)$$

$$E_{O/CCI_{ij}} = b_{ij}^{CCI} \frac{CCI_{ij}}{O_i * PO_i} \qquad (7)$$

The elasticity can be computed at the means of variables (i.e. Mean values of PA, PMA, CCI and O*PO). The result obtained from AAPF and its technical elasticity can be used as a guideline for obtaining Economic Vulnerability Indicators (EVI).

Meanwhile, the Major Operating Cost Structure (MOCS) can also provide some basic information to support the AAPF result since the each "j" Major Operating Cost (MOC) from MOCS can explain a way of each individual's input investment for obtaining their targeted outputs. MOC can be simply calculated by:

$$MOC_j = \frac{MOC_j}{\sum_j MOC_j} \qquad (8)$$

And MOCS can provide a general ranking based on each individual investment for their major input during their aqua-farm activities. In addition to MOCS calculation, a common Feed Conversion Ratio (FCR) can be further transformed to 'modified FCR (mFCR)' as:

$$FCR = \frac{Total\ Feed\ Mass(kg)}{Total\ Body\ Mass(kg)} \Rightarrow mFCR = \frac{Total\ Feed\ Mass(kg) * Feed\ Cost(value/kg)}{Total\ Body\ Mass(kg) * Shrimp\ \mathrm{Pr}ice(value/kg)} \qquad (9)$$

The mFCR is capable of measuring the feed conversion efficiency for both intensive and extensive culture systems through a common ground on a ratio of revenue obtained from feed cost used (direct or indirect feed cost). The optimal range for commercial aquatic animal production FCR, which is equal to 1.2 – 1.5, can be used as a reference for both actual FCR and mFCR comparisons.

In 2009, the 190 Vietnam small-scaled shrimp production data had been collected through a survey technique by 2 provinces; Bạc Liêu (101 samples) and Cà Mau (100 samples), respectively. For Bạc Liêu shrimp AAPF case, a separated wet and dry season production periods have been analyzed. In general, for a dry season, a height of dyke (bottom of ditch to dike top) has been detected from the group of PA variable. The detected PMA variables are Respondent household income from all farm activities, Income from crab and Income from fish, respectively. Meanwhile the Total lime cost is only detected variable from PIA group. However, none of the CCI variables has been detected. The adjust-R2 has indicated a variation incurs in AAPF can explain a variation in the Bạc Liêu shrimp revenue during a dry season by 85.10% (see Table 39).

Table 39: Estimated Parameters of Bạc Liêu Dry Season Shrimp AAPF

AAPF Parameter	AAPF Parameter Value	t-statistics	Std. Error
Constant	6,273,533	2.910	2,156,096
Respondent household income from all farm activities	0.463	20.394	0.23
Total lime cost	-12.311	-4.868	2.529
Income from crab	-0.898	-4.502	0.199

Height of dyke	-3,174,426	-2.463	1,288,831
Income from fish	-1.085	-2.111	0.514

Note: Adj-R2 = 0.851, a = Approximated value, All estimated coefficient is statistically significant at 0.05. All parameter values are statistically significant at 0.05.

The negative (“-“) sign detected in the Bạc Liêu shrimp in dry season for Total lime cost, Income from both crab and fish and Height of dyke (bottom of ditch to dike top) indicate some negative relationship between these detected parameters and the Bạc Liêu dry season shrimp revenue. For instance, a 1 VND spent in the Total lime cost would result in a reduction in Bạc Liêu dry season shrimp revenue by 12.31 VND. Meanwhile the Bạc Liêu dry season shrimp would be reduced by approximately 1 VND as the either income for crab or fish increase by 1 VND. For the Height of dyke (bottom of ditch to dike top), an increase a height by 1 meter would result in a reduction in Bạc Liêu dry season shrimp revenue by approximately 3 million VND.

The positive (“+”) sign detected in Respondent household income from all farm activities variable, on the other hands, indicate a positive relationship between the income from all farm activities and the income from shrimp during the dry season by an increase in all income from all activities by 1 VND would result in an increase of Bạc Liêu shrimp income by approximately half of VND.

For Bạc Liêu wet season shrimp, the only detected PMA variable is Respondent household income from all farm activities meanwhile the Total commercial feed cost is only detected variable from PIA group. However, none of the CCI variables has been detected. The adjust-R2 has indicated a variation incurs in AAPF can explain a variation in the Bạc Liêu shrimp revenue during a wet season by 83.60% (see Table 40).

Table 40: Estimated Parameters of Bạc Liêu Wet Season Shrimp AAPF

AAPF Parameter	AAPF Parameter Value	t-statistics	Std. Error
Constant	-1,215,029	-1.458	833,383.5
Respondent household income from all farm activities	0.386	22.582	0.017
Total commercial feed cost	-2.679	-3.578	0.749

Note: Adj-R2 = 0.836, a = Approximated value, All estimated coefficient is statistically significant at 0.05. All parameter values are statistically significant at 0.05.

As compared to the Bạc Liêu dry season shrimp AAPF, the Respondent household income from all farm activities has still also been found with the positive relationship with the shrimp revenue (wet season). Meanwhile, the Total commercial feed cost is only detected in this wet season shrimp AAPF with the negative sign. It means that an increase in the Total commercial feed cost for shrimp during the wet season in Bạc Liêu by 1 VND would result in a reduction by 2.68 VND for shrimp revenue during the same period.

For Cà Mau shrimp AAPF estimation, the single Cà Mau shrimp AAPF has been analyzed due to their common way of aquaculture system in the area. The only detected PMA variable is Respondent household income from all farm activities meanwhile the Total commercial feed cost is only detected variable from PIA group. However, none of the CCI variables has been detected. The adjust-R2 has indicated a variation incurs in AAPF can explain a variation in the Cà Mau shrimp revenue by 64.70% (see Table 41).

Table 41: Estimated Parameters of Cà Mau Shrimp AAPF

AAPF Parameter	AAPF	t-statistics	Std. Error

	Parameter Value		
Constant	4,812,389	1.70	2,830,730
Respondent household income from all farm activities	0.613	12.842	0.048
Total Commercial Feed Cost	55.377	2.008	27.580

Note: Adj-R2 = 0.647, a = Approximated value, All estimated coefficient is statistically significant at 0.05. All parameter values are statistically significant at 0.05.

All positive signs detected in these variables (i.e. Respondent household income from all farm activities and Total commercial feed cost) indicate a positive relationship between these parameters and the Cà Mau shrimp revenue. An increase in the Respondent household income from all farm activities by 1 VND would result in an increase in Cà Mau shrimp revenue by 0.61 VND. Meanwhile, an increase in Total Commercial Feed Cost by 1 VND would result in an increase in Cà Mau shrimp revenue by 55.38 VND.

The comparative ranking the coefficients of these derived parameters through an elasticity measured at the mean calculation (Table 42 and Table 43) has shown that, without a sign consideration, the highest (most important) concerned parameter, among all statistically significant parameters, for all shrimp activities in both provinces is the Respondent household income from all farm activities. The positive sign for all the Respondent household income from all farm activities elasticity indicates the same direction of the change between this parameter and shrimp revenue. However, with the Respondent household income from all farm activities elasticity of the Bạc Liêu province being greater than one, it indicates more likely to be elastic factor. Compared to Cà Mau with the one's elasticity being less than one, on the other hand, it indicates more likely to be inelastic factor.

Table 42: Elasticity measured at mean calculation and ranking for Bạc Liêu shrimp Wet and Dry Seasons production function

Ranking	AAPF Parameter (Dry Season)	Elasticity	AAPF Parameter (Dry Season)	Elasticity
1	Respondent household income from all farm activities	1.26	Respondent household income from all farm activities	1.10
2	Height of dyke	(0.39)	Total Commercial Feed Cost	(0.01)[a]
3	Income from fish	(0.38)		
4	Total lime cost	(0.37)		
5	Income from crab	(0.29)		

Note: () = Negative value, a = approximated value

Table 43: Elasticity measured at mean calculation and ranking for Cà Mau Shrimp production function

Ranking	AAPF Parameter	Elasticity
1	Respondent household income from all farm activities	0.81
2	Total Commercial Feed Cost	0.00[a]

Note: () = Negative value, a = approximated value

Meanwhile the Bạc Liêu MOCS shows almost equal cost structure distribution throughout the season (approximately 25% for each preparation and culture periods). During the preparation for both seasons, both Total sediment removal cost and Total dike repair cost are major cost with a range between approximately 6 to 9 % to all year cost structure. The highest MOCS during the culture period belongs to Total seed cost with a range approximately between 16 – 17% to all year cost structure (See Table 7). The mFCR values for Bạc Liêu are calculated by dividing total direct and indirect feed costs (i.e. Total commercial feed cost and Total inorganic fertilizer cost) by total revenue from their farming activities (i.e. total income from shrimp, fish, crab and rice). The value of 0.44, 0.30 and 0.35 are calculated mFCR for dry, wet and overall seasons, respectively.

Table 44: Major Operating Cost Structure for Bạc Liêu Wet and Dry Seasons Shrimp Culture

Major Operating Cost	% to Specified Period	% to All Year
Preparation for Dry Season		
Total sediment removal cost	32.52	8.81
Total lime cost	3.52	0.95
Total chemical cost	5.24	1.42
Total Inorganic fertilizer cost	11.74	3.18
Total labor cost	14.45	3.92
Total dike repair cost	27.10	7.34
Total sluice gate repair cost	5.42	1.47
Total	100.00	27.10
Culture Period for Dry Season		
Total drug cost	15.41	3.67
Total electricity cost	15.56	3.71
Total seed cost	69.03	16.45
Total	100.00	23.83
Preparation for Wet Season		
Total sediment removal cost	28.71	7.34
Total lime cost	4.98	1.27
Total chemical cost	5.07	1.30
Total inorganic fertilizer cost	12.44	3.18
Total labor cost	13.40	3.43
Total dike repair cost	22.97	5.87
Total fuel cost	12.44	3.18
Total	100.00	25.58
Culture Period for Wet Season		
Total seed cost	67.50	15.86
Total fuel cost	32.50	7.64
Total	100.00	23.50
Grand Total		100.00

Source: The project survey in 2009. All input values are provided by crop

Total seed cost (35.09% to all year cost structure) followed by Total sluice gate repair cost (29.45% to all year cost structure) and Total dike repair cost (12.27%), respectively (See Table 44). The mFCR values for Cà Mau are calculated by dividing total direct and indirect feed costs (i.e. Total commercial feed cost and Total inorganic fertilizer cost) by total revenue from their farming activities (i.e. total income from shrimp, fish, crab and rice). The value of 0.60 is calculated mFCR for overall season.

Table 45: Major Operating Cost Structure for Cà Mau Shrimp Culture

Major Operating Cost	% to All Year
Preparation	
Total sediment removal cost	19.63
Total inorganic cost	0.98
Total Fuel cost	2.58
Total dike repair cost	12.27

Total sluice gate repair cost	29.45
Culture Period	
Total Seed Cost	35.09

All shrimp AAPF models for all provinces have generally confirmed an improved extensive shrimp culture type. For the Total commercial feed cost parameters which are only detected in Bạc Liêu Wet season and Cà Mau shrimp production but have a zero median value in MFOC calculations for all cases, they indicates how important of this parameter to some extent since both of the parameters have shown different signs (i.e. negative and positive relationships between the shrimp revenue and their Total commercial feed cost for Bạc Liêu Wet season and Cà Mau , respectively). Meanwhile the incomes from other species (i.e. crab and fish) for Bạc Liêu Dry season have shown a negative sign may indicate a problem of farm management practice for polyculture during the period. For mFCR comparison, Bạc Liêu has obtained a higher efficiency for a feed related expense to all farm revenues conversion than Cà Mau 's case (0.35 compared to 0.60 for Bạc Liêu and Cà Mau provinces, respectively). None of CCI variables has been detected in AAPFs' model. No further discussion for any climate impact cannot be produced.

Chapter 5 – Green House Gas Production and Resources Use Marking

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5.1. Introduction

In order to identify culture systems that produce the most GHGs and prioritise better practices for the culture systems with high environmental impact, the different case studies need to be benchmarked against each other and other aquaculture technologies. This analysis uses resource use analysis to estimate the resource use and nutrient impact to the environment and Life Cycle analyses to estimate GHG emission. In this way the aquaculture culture systems that are resource heavy or have high GHG emissions can be highlighted and best practice guidelines to reduce impacts. The analysis assesses the GHG emissions and resource use per tonne of food produced by the case study culture systems.

The Bangkok Declaration expressed the need to develop resource-efficient farming systems which make efficient use of water, land, seed and feed inputs by exploring the potential for commercial use of species feeding low in the food chain. Although significant resource competition exists, significant technological advancements in aquaculture over the past decade have occurred to make production systems less consumptive of land, water and energy, to the point where aquaculture resource use, overall, is comparable to poultry production.

However, the next 20 years will see an increase in the efficient use of land, water, food, seed and energy through intensification and widespread adoption of integrated agriculture-aquaculture farming ecosystems approaches. However, this will not be enough to increase aquaculture production as these will improve only the efficiency of use, and increase aquaculture yields per unit of inputs. An exponentially growing population will require aquaculture to expand rapidly into land and water areas that are currently held as common pool resources (commons). This raises issues of access to and management of common pool resources, which could result in conflicts with exiting users and potentially acute social, political, and economic problems.

Assessing environmental performance of aquaculture is difficult because activities and potential impacts are extremely diverse. However there is an increasing emphasis on using holistic analyses to compare overall impacts of different agricultural production systems and to assess impacts and resource use within a production process to identify opportunities for increasing resource use efficiency. Life Cycle Assessment is the most common comprehensive analytical tool currently used to quantify environmental impacts of production process. The LCA concept has been formalized into an analytical methodology under ISO 14000 standards and has been proposed as a measure of environmental performance and sustainability by numerous agencies and environmental groups

The LCA approach is useful because the impacts of all activities involved in production, use, and retirement of a product are expressed in a single "common currency"—energy use, for example—thereby making it easy to compare impacts among various products, processes, or activities. Life cycle assessment must have clearly defined boundaries because impacts can, in theory, flow almost endlessly upstream and downstream of the actual production process. For example, an energy LCA for aquaculture may include energy costs to procure pelagic fish for reduction to fish meal that will be used in aqua-feeds. The energy cost of fishing is primarily embodied in the fuel used by the fishing vessel, but can also include the energy used to manufacture the fishing vessel, to produce the steel and fiberglass used to fabricate the vessel, to produce the nylon used in nets, and so on. In this analysis the boundary for analysis is set to the production phase only. Production data and resource use was collected through detailed questionnaires from owner operators. Combining the power of LCA with individual resource use indicators based on specific impacts provides a comprehensive set of tools for assessing environmental performance.

5.2. Feed use

Nutrient requirement for the fish and shrimp production in ponds is provided either by natural productivity of the pond or by feed. This ratio varies with the culture system. A large proportion of the nutrient requirements for semi-intensive milkfish pond and shrimp pond production are provided by pond water productivity (phytoplankton, zooplankton and other micro organisms) which is enhanced by using organic and/or inorganic fertilizers. On the other hand, almost all the nutrient requirements for intensive Pangasius catfish pond production are provided by inert feeds. In some cases aquaculture feed often incorporates high levels of fish meal and fish oil provided from wild stocks and so aquaculture fish may not be a net producer of fish.

Aqua-feeds usually are the most costly aquacultural input, and feed ingredient production, feed manufacture and feed transport constitute large proportion of energy inputs to aquaculture production.

The efficiency of feed use varies between species, feed quality and feeding strategy. This can vary between culture systems and species where the feed conversion rate far salmon is close to 1:1, Milkfish cage production at 2.5:1 using inert feeds to grouper cage production at 5:1 using trash fish.

Not all the nutrients proficed through the feed are taken up by the fish with the majority of nutrients lost to the environment either as solids (uneaten feed or feces) or as dissolved nutrients (excretion). These nutrients are assimilated by the environment but if there are excess nutrients, they can form an anoxic layer on the seabed surface or cause eutrophication or trigger algal blooms. It also is significant to note that the amount of waste generated per unit of production decreases as the FCR declines.

The most widely used indicator of production and feed use efficiency in aquaculture is the feed conversion ratio (FCR). This indicator is calculated as follows:

$$FCR = \frac{Feed\ provided\ (kg)}{Net\ aquacultural\ production\ (kg)}$$

Aquaculture uses most of the world’s fishmeal (68%) and fish oil (88%) with the balance used by intensive livestock agriculture and for pet foods (Tacon, 2005; Tacon et al., 2006; Tacon and Metian, 2008). Salmon, trout and shrimp aquaculture which account for less than 10% of world aquaculture production, use an estimated 26% of the world’s fish meal, but 74% of the fish oil (Tacon and Metian, 2008). However, Tacon and Metian (2008) predict that fishmeal and oil use in aquaculture will decrease while aquaculture production grows significantly, and that fish meal/oil will increasingly be diverted from uses as bulk feed products to high priced, specialty, feed ingredients.

Fish oil:

Fish oil also is a component of some of aquaculture feeds. There is a finite supply of fishmeal and oil. Because fish oil has traditionally been viewed as a by-product of fish meal production, more concern has been expressed in the past about the fish meal supply than the fish oil supply. The yield of fish oil from reduction fisheries is significantly lower than the yield of fish meal. This suggests that fish oil may in the future be a scarcer commodity than fish meal for use in aquafeeds. It takes 10 to 20 kg live fish to produce a kilogram of fish oil, but the quantity varies greatly by species and season (Tacon et al., 2006).

However, "fish-oil ratios" and feed-fish equivalences that include oil are more difficult to calculate and interpret than those for fishmeal because of the large variation in fish oil yield and the history of fish oil as a by-product of fish meal production. Nevertheless, the wild fisheries conservation benefit of substituting vegetable oil for fish oil in aquafeeds is great. The main problem with complete substitution is that marine species need long-chain polyunsaturated fatty acids in their diet and fish oils are an excellent source. Also, the fatty acid profile of fish produced on feeds containing only vegetable oil is different than fish produced with feeds containing fish oil, and this may change the taste of the fish.

Fish meal:

Fish used for making fish meal are provided primarily from wild pelagic fishery. In fish meal manufacturing, the ratio of live fish to fish meal is about 4.5. Fish meal can also be produced from the offal from processing of wild-caught or aquacultured fish. Offal contains more ash and less protein than live fish, and fish meal from offal is of lower quality than that from live fish. Nevertheless, fish meal from offal can be used in many applications to supplement marine fish meal. Shrimp heads from processing can be used to make shrimp head meal that can be used in animal feeds.

Environmentalists are concerned over inefficient use of feed fish to make fish meal and fish oil for aquafeeds. Feed fish are a component of world fisheries production, and it can be logically argued that unless a Fish-in to fish out ratio (FIFO) of 1.0 or less is obtained, feed-based aquaculture detracts from world fisheries production.

Currently, about 40% of aquaculture depends on formulated feeds: 100% of salmon, 83% of shrimp, 38% of carp (Tacon and Metian, 2008). An estimated 72% of all use of global aquafeeds is by low trophic level herbivorous and omnivorous aquatic organisms (carps, tilapias, milkfish and shrimp) each of which dominates in various countries.

Fish-in Fish-out Ratio (FIFO):

One of the current concerns in the aquaculture sector is the amount of wild fish that is required to produce farmed fish. A number of different methods have been developed to calculate the amount of wild fish that it takes to produce one tonne of farmed fish. One such methodology is based on the Fish-in : Fish-out ratio (FIFO ratio). Using dry pellets, FIFO ratios for salmon range between 3:1 to 10:1 with Tacon and Metian (2008) calculating a FIFO ratio of 4.9:1 for salmon production, indicating that 4.9 tonnes of wild fish are required to produce 1 tonne of farmed salmon.

A number of authors have developed methodologies for calculating FIFO ratios. These include:

- Tilapia Aquaculture Dialogue draft v2.0 (WWF, 2009),

- Tacon and Metian (2008),
- International Fishmeal and Fish Oil Organisation (IFFO) methodology (Jackson, 2009),
- EWOS methodology for fatty fish such as salmon (EWOS, 2009)

Table 46: Trends in Fish-In Fish-Out Ratios from 1995 to 2008

Subsidised aquaculture	FIFO (1995)	FIFO (2008)
Salmon	7.5	4.9
Trout	6.0	3.4
Eels	5.2	3.5
Misc. Marine Fish	3.0	2.2
Shrimp	1.9	1.4
Net production aquaculture		
Chinese and Indian major carps		0.2
Milkfish		0.2
Tilapia		0.4
American catfish		0.5
Freshwater prawns		0.6

Source: Tacon and Metian (2008).

The following provides a brief review of the assumptions that are used in the various models:

Tilapia Aquaculture Dialogue draft v2.0 Methodology:

These models are based on the weight of fish caught and produced, and provide Fish Feed Efficiency Ratios for fishmeal and fish oil.

$$\text{FFERmeal} = \frac{(\%\text{ fish meal in feed}) \times (\text{eFCR})}{22.2}$$

$$\text{FFERoil} = \frac{(\%\text{ fish oil in feed}) \times (\text{eFCR})}{5.0}$$

The model assumes that the fishmeal produced from the fish caught for fish oil is wasted.

Tacon and Metian (2009):

The method used by Tacon and Metian (2009) effectively assumes that the excess fishmeal produced from the fish caught for fish oil is wasted. In fact it is used as ingredients and materials for other feed production. The IFFO (2009) method addresses this issue, but fails to recognize that cultured salmon have a higher lipid level than the average wild fish. The models assume a yield of fishmeal and fish oil of 22.5 and 5 percent on a wet weight to dry weight basis respectively.

IFFO methodology (Jackson, 2009):

The IFFO method applies the following equation:

$$\text{IFFO FIFO Ratio} = \frac{\text{Level of fishmeal in the diet + level of fish oil in the diet}}{\text{Yield of fishmeal from wild fish + level of fish oil from wild fish}} \times \text{FCR}$$

This model corrects the Tacon and Metian (2009) model that implies that the extra fishmeal is wasted and takes into account of both the fishmeal and fish oil use. However, the model is biased against fish with high lipid levels such as salmon, trout and eels due to the differential between some species of cultured fish with high lipid level compared to wild fish used for the production of fish meal and fish oil.

EWOS methodology:

The EWOS model compensates for fish that have relatively high fish oil concentrations (e.g. salmon) on the basis of nutrients used and produced, and compares the ratios using the same assumptions (fish meal and fish oil yields). The nutrient based ratio corrects this bias, and is the preferred ratios to use for fatty fish such as salmon, trout and eels. The calculations are as follows;

For Marine Protein.

$$\text{Marine Protein Dependency Ratio} = \frac{\text{kg marine protein used}}{\text{kg marine protein produced}}$$

$$\text{MPDR} = \frac{\text{FMfeed x PrFM x eFCR}}{\text{PrtSalm}}$$

where

MPDR Marine Protein Dependency Ratio
FMfeed Concentration of fishmeal in the feed (%)
PrFM Concentration of protein in fishmeal (as a proportion)
eFCR economic Feed Conversion Ratio
PrtSalm Concentration of protein in the salmon on whole fish basis (%)

For Marine Oil

$$\text{Marine Oil Dependency Ratio} = \frac{\text{Kg marine oil used}}{\text{Kg marine oil produced}}$$

$$\text{MPDR} = \frac{\text{(Fofeed x FMfeed x FoFM)) xeFCR}}{\text{OilSalm}}$$

where

MODR Marine Oil Dependency Ratio

FoFeed Concentration of fish oil in the feed (%)
FMfeed Concentration of fishmeal in the feed (%)
FoFM Concentration of fish oil in fishmeal (as a proportion)
eFCR economic Feed Conversion Ratio
OilSalm Concentration of oil in the salmon on whole fish basis (%)

For the purpose of this report, the IFFO formula was adopted and used to analyse the results of this study as the trial species do not have high lipid levels when compared to salmon, and accounts for other uses of the unused fishmeal and fish oil which is not the case with the method used by Tacon and Metian (2009).

The estimated FIFO ratios for the case study culture systems used the following formula;

$$\frac{\text{Level of fishmeal in the diet} + \text{level of fish oil in the diet}}{\text{Yield of fish meal from wild fish} + \text{yield of fish oil from wild fish}} \times \text{FCR}$$

The results indicate that the FIFO ratio for the case study culture systems was as follows:

Table 47: Results of AquaClimate case study analysis for FIFO Ratio

Case study culture system	**FIFO**
Shrimp pond culture, India	1.23
Pangasius pond culture, Vietnam	0.28
Polyculture pond culture, Vietnam	0.07
Milkfish pond culture, Philippines	0.00

The case study results were benchmarked against other estimated FIFO ratios as follows:

Table 48: Fish In Fish Out Ratios (Adapted from Tacon and Metian, 2008)

Subsidized aquaculture	**FIFO (2008)**
Salmon	4.9
Trout	3.4
Eels	3.5
Misc. Marine Fish	2.2
Shrimp	1.4
Shrimp in India (AC)	1.23
Net production aquaculture	
Freshwaterprawns	0.6
American catfish	0.5
Tilapia	0.4
Pangasius catfish	
Chinese and Indian major carps	0.2
Milkfish	0.2
Polyculture in Vietnam (AC)	0.07
Milkfish in Philippines(AC)	0.0

*AC = AquaClimateresults

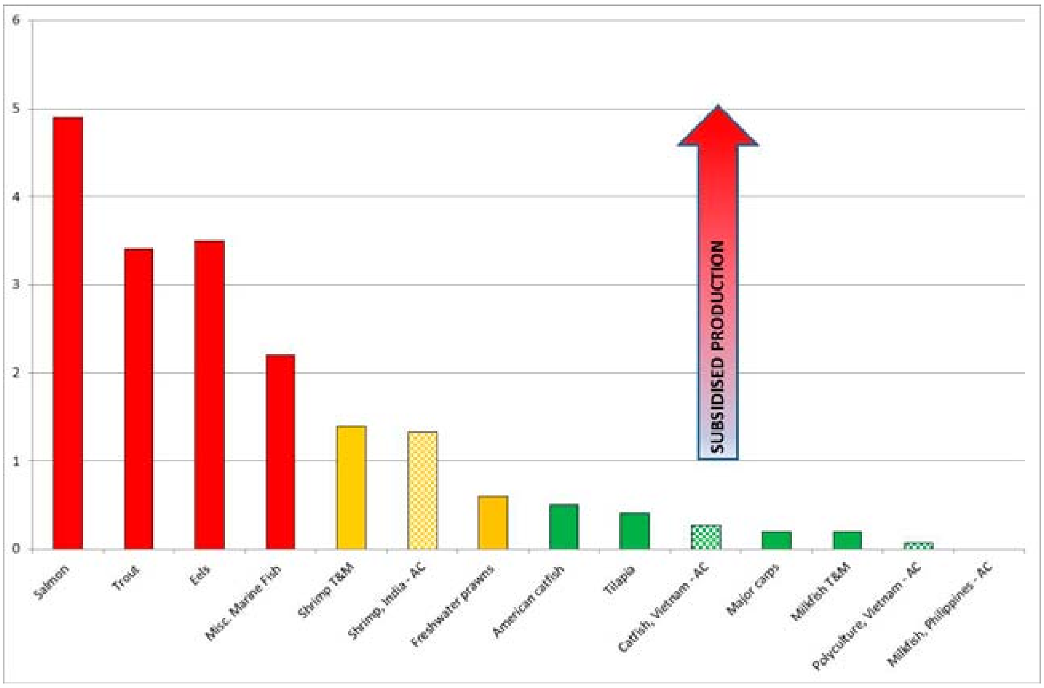

Figure 34: Comparison of wild fishery resource use efficiency (Fish-in Fish-out ratio)

5.3. Water use

Water use in aquaculture can be extreme—as high as 45 m3/kg of fish production (FAO). The potential for increased water use efficiencies in aquaculture is higher than terrestrial systems. Globally about 1.2 m3 (or 1200 liters) of water is needed to produce 1 kg of grain used in animal feed (Verdegem et al., 2006). A kg of tilapia can be produced with no consumptive freshwater use (cages, seawater farming systems), or using as little as 50 L of freshwater (Rothbard and Peretz, 2002). Seawater aquaculture systems (mariculture) can use brackish waters unsuitable for agriculture; plus, integrated, land-based saltwater faming is possible (Fedoroff et al., 2010).

Water use in aquaculture may be classified as either total use or consumptive use (Boyd,2005). Total water use is the sum of all inflows (precipitation, runoff, seepage, and management additions) to production facilities. Much of the water entering production facilities passes downstream in effluent discharge. Consumptive water use includes reduction in stream flow as a result of increased evaporation and seepage from the aquaculture facility, freshwater from wells, and water removed in biomass of aquatic animals at harvest (Boyd, 2005). Water in harvest biomass average about 0.75 m^3/t, a minor quantity that usually can be ignored.

Boyd (2005) proposed indices for water use and water value that can be calculated for either total or consumptive use as follows:

$$Water\ Use\ Index\ (m^3 / tonne) = \frac{Water\ use\ (m^3)}{\Pr oduction\ (tonne)}$$

Total water use varies greatly in aquaculture depending mainly upon the culture method used. Cage and net pen culture use water passively as it passes through the nets by the currents and raceway culture uses the most water where water actively passes through the tanks by gravity or pump. Water use in ponds varies with the intensity of production, frequency of draining, and amount of water exchange employed.

Consumptive use of freshwater in aquaculture is an important conservation issue. Total and consumptive water use is the same for cage and net pen culture, for the only water consumed is that incorporated into biomass. In raceway culture, water in biomass plus evaporation from raceways is consumptive use.

Table 49: Results of AquaClimate case study analysis for water use

Case study culture system	m^3/t
Polyculture pond culture, Vietnam	50,179
Shrimp pond culture, India	33,155
Milkfish pond culture, Philippines	8,010
Pangasius pond culture, Vietnam	1,327

These results were benchmarked against other estimates of water resource use as follows:

Table 50: Low water use - Average use less than 3000 cubic meters/tonne product.

Systems	Estimated water use (m^3/tproduct)	Comments
Seawater farming (halophytes, marine fish, shellfish, seaweeds, euryhaline fish such as tilapia)	0-100	Freshwater use is for makeup waters to replace evaporation in land-based farming systems. Hodges et al. (1993);www.seawaterfoundation.org; Federoffet al. (2010)
Recirculating aquaculture systems	500-1,400	Intensive Africacatfish, eel and turbot fed complete feeds Verdegem et al. (2006)
Pangasius culture in Vietnam	1,327	Intensive striped catfish culture in ponds using complete feeds. AquaClimate
Freshwater fish production	2,700	Intensively mixed pond with production of 100 MT/ha/yr. Verdegem et al. (2006)
Tilapia	2,800	Brummett (1997)

Adapted from Costa-Pierce

Table 51: Medium water use - Average use 3000-10,000 cubic meters/tonne product

Systems	Estimated Freshwater Use (m^3/tproduct)	Comments
Catfish	3,350 (with reuse for irrigation)	Brummett (1997)
Catfish	4,000-16,000 (low – undrained embankment ponds, high –drained watershed ponds)	Eliminating well water as consumptive use would decrease water use in embankments ponds to 2,600-3,200.Boyd (2005)
Fish in freshwaterponds	5,200	If infiltration, drainage and recharge are considered green

		water
Pangasius catfish Vietnam	6,400 average industry wide	Phan et al. (2009)
Fish in freshwaterponds	4,700-7,800	Production of 10-20 MT/ha/yr with night time aeration
Milkfish culture in the Philippines	8,010	Semi-intensive milkfish culture in ponds using supplementary feeds. AquaClimate

Table 52: High water use (average use >10,000 cubic meters/tonne product)

Systems	**Estimated water Use (m^3/t product)**	**Comments**
Shrimp farming in ponds	11,000–43,000	Beveridge et al. (1991)
Fish culture	11,500	Fed freshwater species Verdegem et al. (2006)
Trout (90% recycling)	25,000 (252,000 withdrawal)	Brummett (1997)
Fish in freshwater ponds	30,100	Production of 30 MT/ha/yr with20% water exchange Verdegem et al. (2006)
Shrimp culture in India	33,155	Semi –intensive striped monodon shrimp culture in ponds. AquaClimate
Extensive fish culture	45,000	No feedVerdegem et al. (2006)
Polyculture in Vietnam	50,179	Improved extensive polyculture in ponds. AquaClimate
Pangasius catfish Vietnam	up to 59,700	Wide range from 700 to 59,700 Phan et al. (2009)
Trout (75% recycling)	63,000 (252,000 withdrawal)	Brummett (1997)

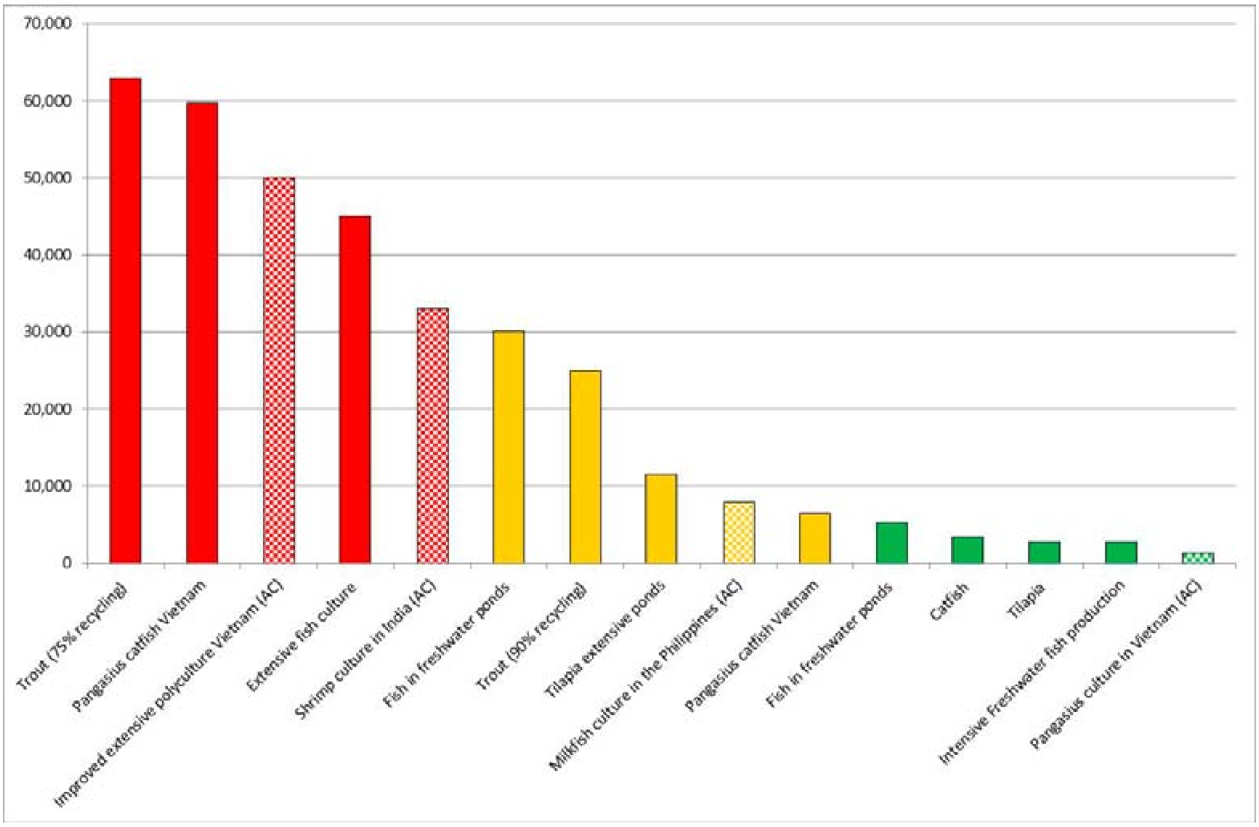

Figure 35: Comparison of direct water use efficiency (m^3/t)

Total water use is important where water is pumped into aquaculture facilities, for there is an energy cost for doing so. In marine shrimp culture, large amounts of water may be pumped into ponds to effect water exchanges. Total water use also is important where water right issues are involved.

Competition may occur between aquaculture and other water uses (Yoo and Boyd,1994; Boyd et al., 2005). Withdrawal of groundwater for use in ponds may lower water table levels and lessen the discharge of other wells in the vicinity. Installation of several ponds on a watershed may lessen downstream flow. Some large, flow-through aquaculture facilities may take water from streams, irrigation systems, or other sources and discharge into different water courses. Although these aquaculture facilities do not consume large amounts of water, they may alter downstream flow patterns and lessen the amount of water available to other users. Cage and net pen culture consumes little water and coastal ponds for brackish water aquaculture consume none. Nevertheless, these facilities may interfere with the use of water bodies or adjacent land areas by other resource users.

5.4. Energy use

There are many uses of energy in aquaculture including energy used for construction of facilities, production of liming materials, fertilizers, production and transport of feed and feed ingredients, operation of machines and vehicles during culture and harvesting, processing, transportation, etc. However, only two of these energy inputs can be readily estimated at the farm level. These are energy uses for pumping water and for mechanical aeration, and, at the farm level, they are the major, direct energy inputs. This discussion will be limited to pumping and aeration, but studies of total energy use per tonne of aquacultural production should be conducted for a number of species and culture methods.

Mechanical aerators powered by internal combustion engines or electric motors are used to supplement the natural supply of dissolved oxygen in grow-out systems. Aeration allows greater stocking and feeding rates to increase production.

Aeration rates in pond aquaculture often are expressed in horsepower per hectare or horsepower applied per volume (Boyd and Tucker, 1998). In channel catfish farming, aeration usually is applied at 4 to 8 hp/ha, while in intensive marine shrimp culture, rates of 10 to 30 hp/ha may be applied. Use of electricity typically is measured in kilowatt/hours (kW/h), and 1 hp = 0.745 kW. However, there are inefficiencies in the use of electricity by machines, and for aerators, the typical efficiency is about 90% (Boyd, 1998). Thus electricity use for aeration can be estimated as follows:

$$\text{Aeration energy, kW} = \frac{\text{Aerator power, hp} \times \text{Aeration time, hr} \times 0.745\ \text{kW/hp}}{\text{Production, t} \times 0.9}$$

Aerators in channel catfish ponds in the southeastern United States normally are operated between May and September for about 10 h/night. Aeration at 6 hp/ha in a catfish pond will use 7,599 kW/h of electricity during a crop year or about 950 kW/h/t for production of 8,000 kg/ha.

Production of marine shrimp in a pond with 15 hp aeration/ha might be 8,000 kg/ha for a 120-day crop. Aeration usually is supplied 24h per day for at least 100 days, but only half of the aerators may be operated during the day. The total electrical use will be about 27,000 kW/h or 3,375 kW/h/t—over three times the amount of aeration used for channel catfish.

In Asia, paddlewheel aerators often are driven by small, internal combustion engines powered by diesel fuel or gasoline. Energy use can be estimated from fuel consumption; 1L diesel fuel is equal to 3.27 kW/h while 1 L of gasoline equates to 2.21 kW-h (Yoo and Boyd, 1994).

The energy use for pumping water to supply ponds can be estimated as follows:

$$P = y\frac{QH}{E}$$

Where: P = power required by pump (kW)

γ= specific weight of water (9.81 kN/m^3)

Q = discharge (m^3/sec)

H = pumping head (m)

E = pump efficiency (decimal fraction).

Boyd and Tucker (1995) used this equation and water management data to estimate that about 1,275 kW/h of electricity typically would be used to fill a 1-ha channel catfish ponds. Annual energy use for pumping water to maintain water levels would be less than 500 kW/h in humid climates and up to 2,000 kW/h in arid climates. Assuming total energy use of 1,775 kW/h//ha per year for catfish ponds in a humid climate, the energy use for pumping would be about 296 kW/h/t as compared to 950 kW/h/t for aeration.

In semi-intensive shrimp culture, ponds are about 1.2 m deep and water often is exchanged at 5% of pond volume daily. The average lift for the water is 3 m. The pump discharges 3 m3/sec at 85% efficiency, and from Equation 16, the pump power is 103.9kW. Initial filling of ponds for each crop will require 12,000 m3/ha of water and the water exchange requirement is 600 m^3/day. Assuming a production of 1.2 t/ha during a 120-daycrop, the total water requirement would be 84,000 m3/ha, and the pump would operate for 7.78 h and use 808 kW/h of energy. This would be equal to 673 kW/h/t of shrimp much less than the energy requirement for aeration of intensive shrimp ponds.

Table 53: Results of AquaClimate case study analysis for land use

Case study culture system	MJ/t
Shrimp pond culture, India	57,718
Pangasius pond culture, Vietnam	1,287
Polyculture pond culture, Vietnam	517
Milkfish pond culture, Philippines	2

These results were benchmarked against other estimates of water resource use as follows:

Table 54: Efficiencies of energy use for aquaculture system

Food Systems	Production(MT/ha)	MJ/MT	References
Canada Salmon Net Pen Water-Based	1,000	26,900	Ayer and Tyedmers (2008)
Canada Salmon Bag System Water-Based	1,733	37,300	Ayer and Tyedmers (2008)
Canada Salmon Flow-through Land Based	2,138	132,000	Ayer and Tyedmers (2008)
Canada Salmon Recirculation Land-Based	2,406	233,000	Ayer and Tyedmers (2008)

Adapted from Costa-Pierce

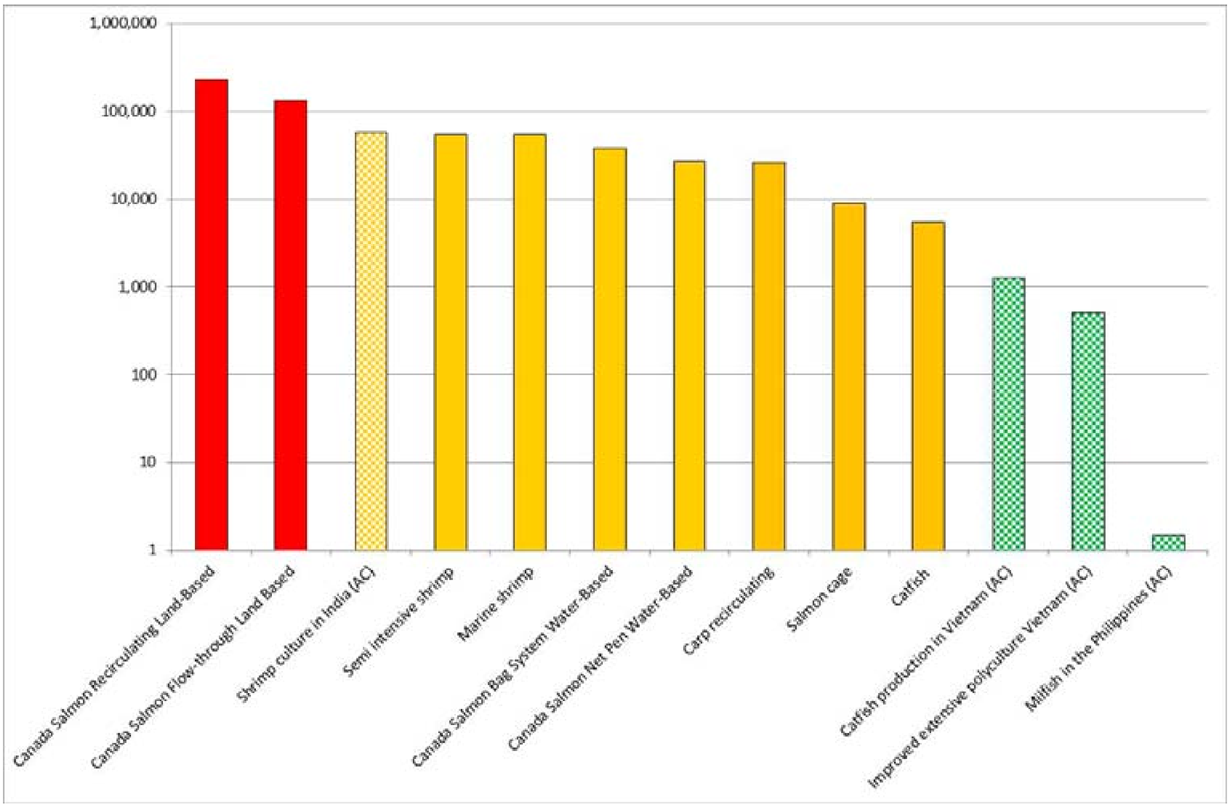

Figure 36: Comparison of direct energy use efficiency (MJ/t)

Studies using modified LCA methodology consistently show that the energy used to produce aquafeeds dominates the energetics of aquaculture production. For example, more than 75% of the total energy cost of producing Atlantic salmon in net pens issued in procuring or growing feed ingredients and manufacturing the feed (Folke, 1988; Troell et al., 2004; Tyedmers, 2004; Ellingsen and Aanondsen, 2006). The remaining energy inputs, in order of importance, were fuel and electricity used to operate the facility, embodied energy costs (manufacture, maintenance, etc.) associated with physical infrastructure, and energy used to produce smolts). Feed production dominates the energy budgets of all aquaculture systems relying on aquafeeds, regardless of species (Troell et al.,2004).

Life-cycle assessment of energy use can include post-harvest functions such as processing, freezing, refrigeration, storage, transportation, marketing, waste treatment, and even household activities such as refrigeration, freezing, and cooking. Energy use in these activities apparently has not been assessed for aquaculture but may be an important part of the overall energy costs of delivering aquaculture products to a consumer's plate. For example, energy used in on-farm production of the United States food supply accounts for only about 20% of the energy used to deliver food to the consumer's plate (Heller and Keoleian, 2000). Post-harvest processing and transportation each consume about 15% and household preparation accounts for more than 30% of the total energy consumed. Ultimately, it will be economically and socially imperative to improve the energy efficiency of all aspects of the food-supply chain. However, it is possible that greater overall gains in energy savings can be made by improving the efficiencies of processing, transport, retailing, and even household storage and preparation than can be made by improving energy efficiency in the production sector. This may have particular relevancy in aquaculture, where important products are produced only in certain regions (marine shrimp in the tropics; salmon in the north-temperate) and are stored and shipped long distances for ultimate consumption.

Energy comparisons between systems have become part of more detailed analyses of life cycles (Papatryphon et al., 2004; Ayer and Tyedmers, 2008). Comparisons of these with terrestrial farming show clearly the huge production benefits of intensive aquaculture albeit at a much higher energy cost, contained mostly in feed (Ayer and Tyedmers, 2008). Over the coming decades, increasing global energy, processing, shipping/transportation costs of both products and feeds are predicted (FAO, 2008; Tacon and Metian, 2008).

Chapter 6 – Predicted Climate Change 2020 and 2050

6.1. CSIRO model

The case study Provinces of Cà Mau and Bạc Liêu were analysed for future predicted climate change using the downscaled CSIRO Climate model with the SRES Scenario A2 – Business as usual for the years, Present, 2020 and 2050.

The area was modeled at 2 scales - the provincial level and the Mekong river catchment basin. This allowed analysis of precipitation in the Mekong river catchment to predict river flows and precipitation and temperature at the farm level

Figure 37: Mekong River Basin

The predicted monthly precipitation in the Mekong River catchment area is predicted to be similar between the present and 2020.

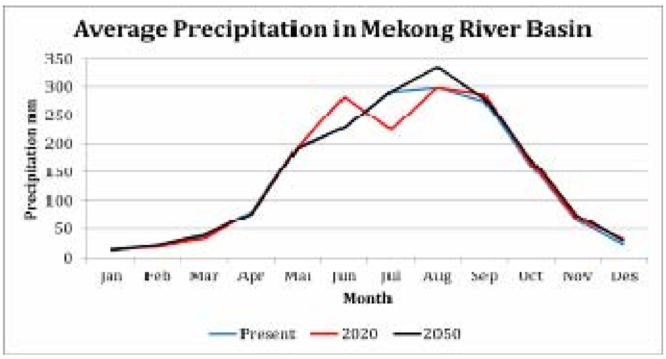

Figure 38: Predicted precipitation in the Mekong River Basin

However, peak rainfall is predicted to be 10% higher in the month of August meaning that at peak river flow, 10% additional water may be passing down the river. This together with the increasing sea level will increase the risk of floods. However, the Mekong is already heavily dammed, with many more dams planned and under construction.

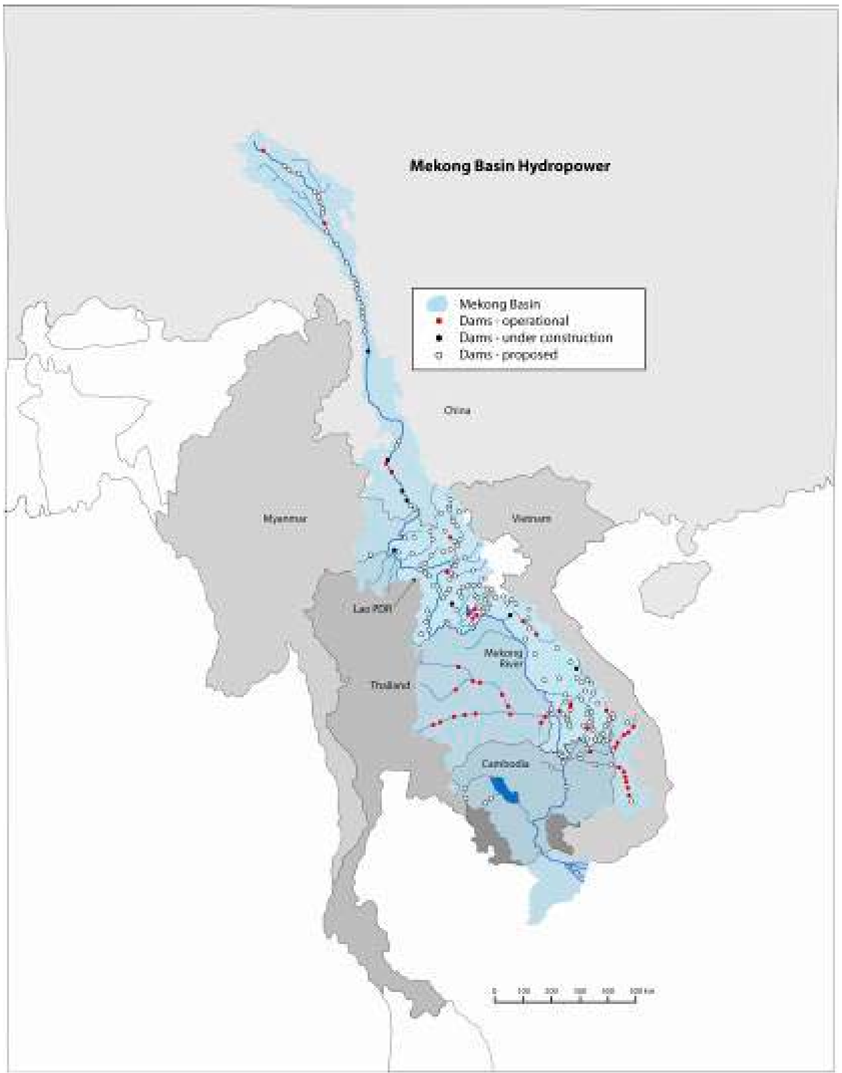

Figure 39: Constructed and planned dams along the Mekong River

Peak riverflow may therefore be controlled by 2050 resulting in less flooding than predicted but with slight increase in severity and extent in the north of Bạc Liêu and the North-east of Cà Mau .

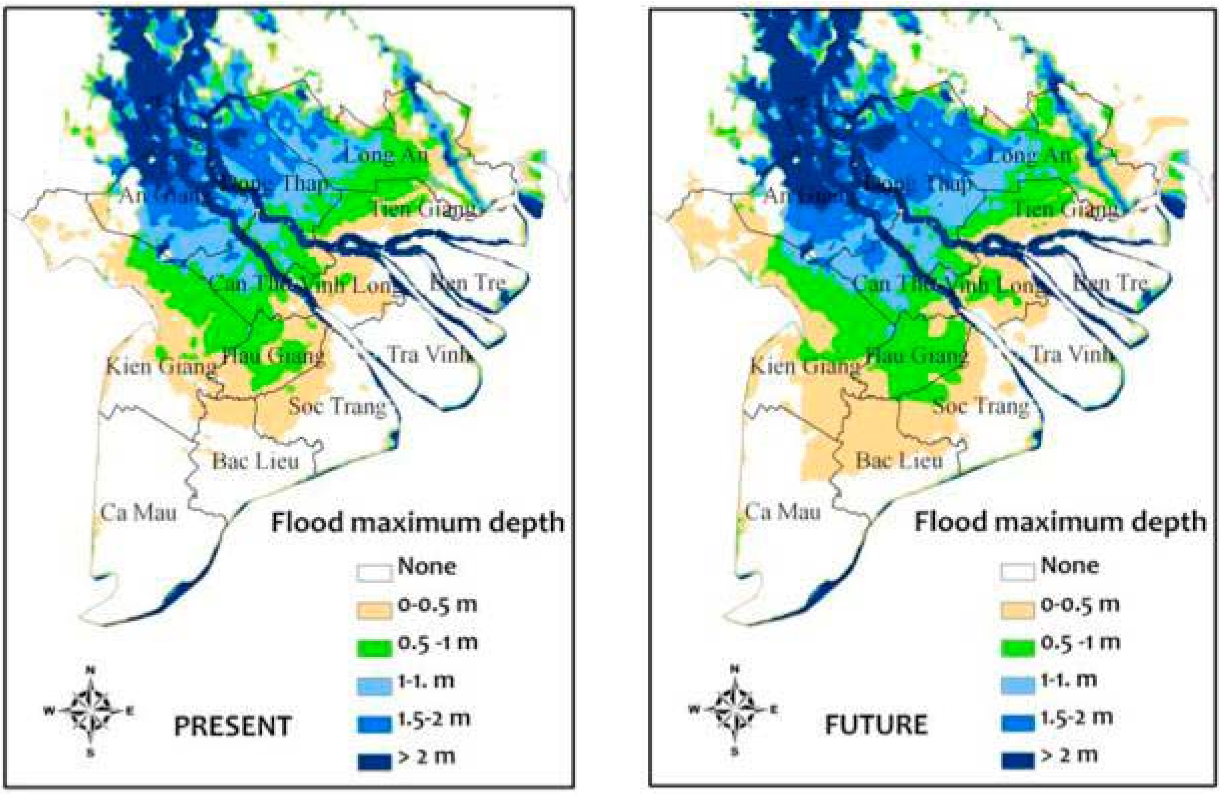

Figure 40: Predicted flood extent and severity

6.2. Temperature

Average monthly maximum temperature:

The average monthly maximum temperature is predicted to rise with time. It is predicted that average monthly maximum temperatures will increase by 0.7°C by 2020 and 1.32°C by 2050 and that present maximum monthly temperatures will be the same temperature or more for 2.5 months (March to May).

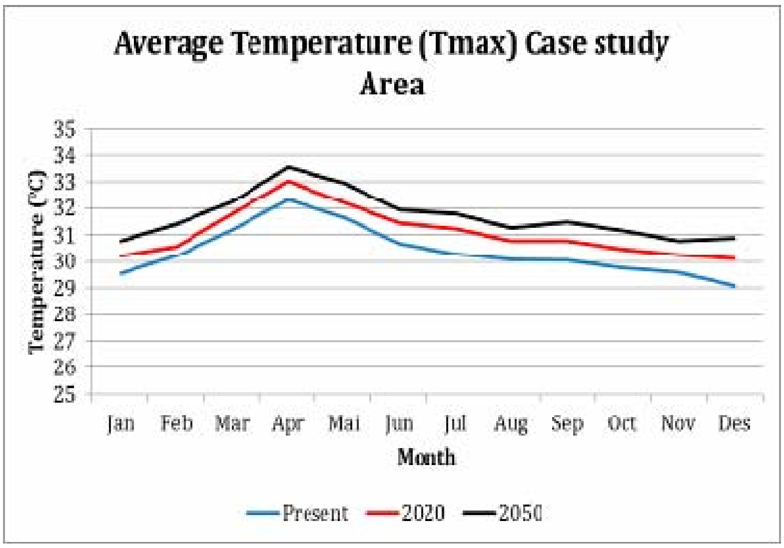

Figure 41: Average monthly maximum temperature at the Province level

Peak Max monthly temperature:

The peak maximum temperatures are predicted to increase in April. It is predicted that average monthly maximum temperatures will increase by 0.83°C by 2020 and 1.33°C by 2050. The peak monthly temperatures will be 1°C higher (35°C) in 2020 and 2°C higher (36°C) in 2050.

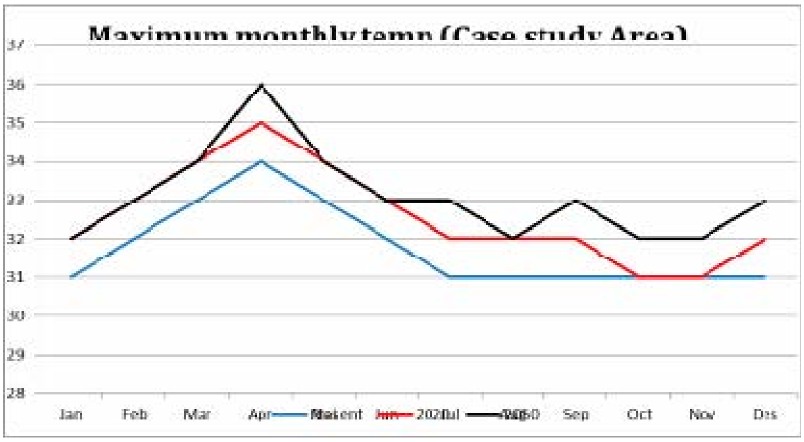

Figure 42: Predicted peak maximum monthly temperatures at Provincial level

This could cause thermal stress for the shrimp at peak maximum temperatures as well as low water oxygen levels and possible impact to pond productivity.

Minimum monthly average temperature:

The average monthly minimum temperature is also predicted to rise. The shrimp will benefit from warmer temperatures between June and January leading to improved growth rate, improved pond productivity and reduced white spot disease outbreaks.

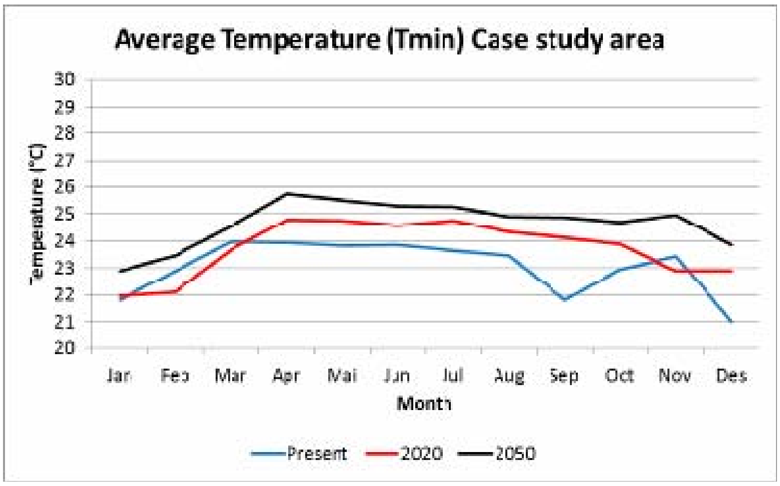

Figure 43: Minimum monthly average temperatures at Provincial scale

6.3. Precipitation

The precipitation at the case study provinces is predicted to be very similar to present precipitation levels.

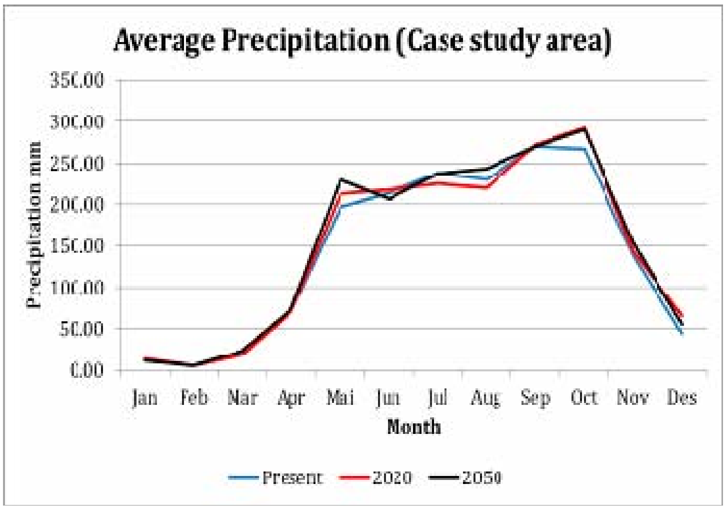

Figure 44: Predicted precipitation in the case study provinces

Although the precipitation at the case study areas is not predicted to change significantly in total rainfall and the seasonality of the precipitation will remain the same, the IPCC predicted (IPCC 2007) that when rainfall occurs, it will be heavier i.e. there will be stronger downpours of rain.

6.4. Sea level rise

Sea level is predicted to rise with time.

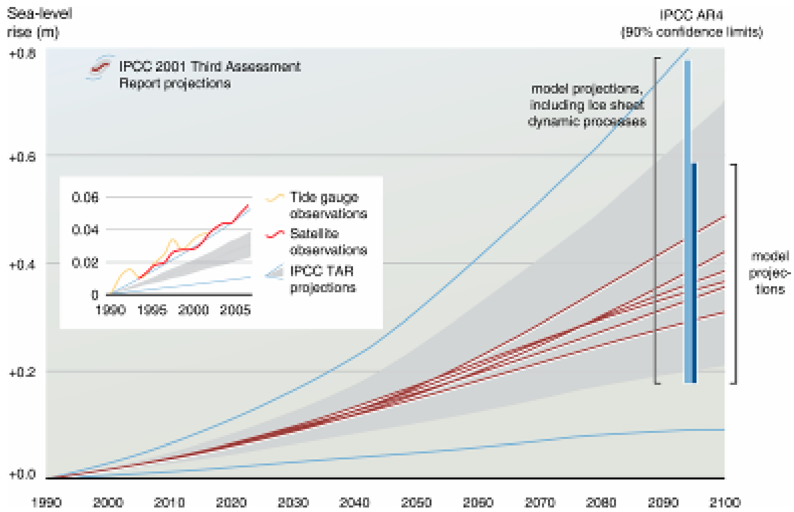

Figure 45: Predicted sea level rise

If the observed sea level rise continues at the present rate then sea level could be 12cm higher in 2020 and 30 cm higher in 2050.

This in conjunction with increased storms will mean stronger and pmore frequent storm surges and seawater flooding of farms close to the coast and in lowlying areas.

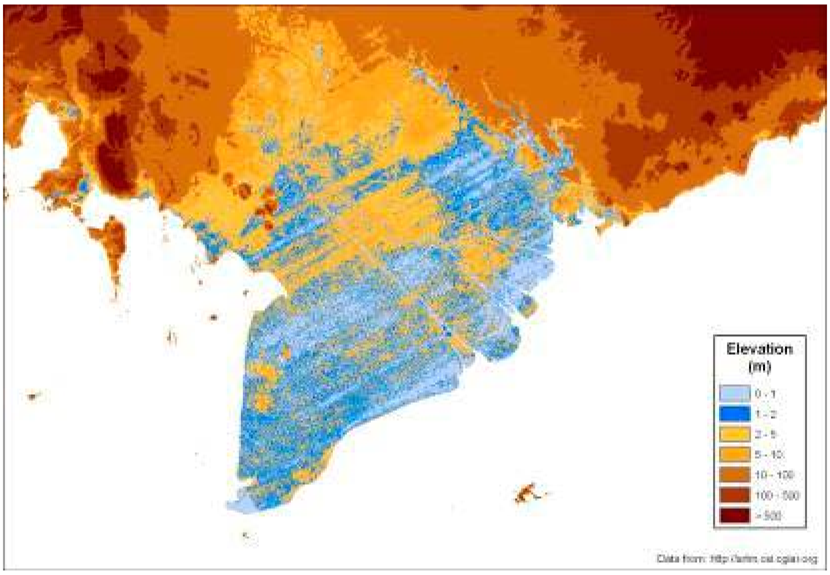

Figure 46: Elevation of the Mekong river delta above present sea level

Increasing sea level rise will also result in increased saltwater intrusion into the Mekong river delta area with increasing salinity December to March and increasing salinity deeper into the delta.

6.5. Ocean acidification

Continuing Carbon emission from the burning of fossil fuel for electricity production and for transport will be taken up in increasing amounts by the ocean leading to increased acidification and decrease in pH.

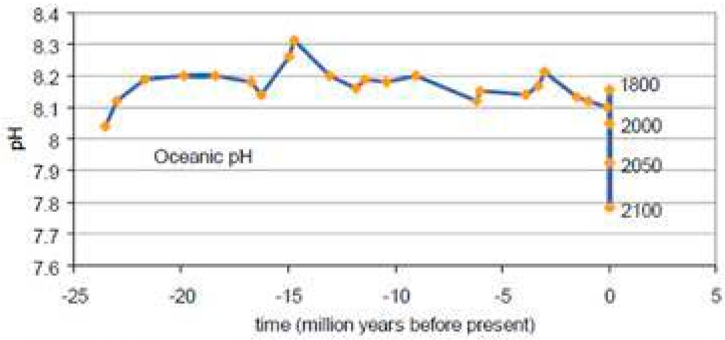

Figure 1. Past and contempory variability of marine pH. Future predictions are model derived values based on IPCC mean scenarios (from Turley *et al*, 2006. Cambridge University Press, 8, 65-70).

Figure 47: Predicted ocean acidification

It is predicted that ocean pH will be below 8 by 2020 and close to 7.9 by 2050. At pH of 7.8 coral, molluscs, and plankton production will be greatly affected and shrimp larval development delayed.

Chapter 7 – Recommended Adaptation Measures for Future Predicted Climate Change

7.1. Climate change scenarios and opportunity in the Mekong Delta

Generally, farmers in the Mekong Delta have already observed irregular weather/extreme pattern events for the last decades, they therefore have been adaptive to the extreme events almost by themselves. They identified five events of climate change impacted their shrimp farming: irregular seasonal changes, hot weather, water level rise, storm, and too much rain. Irregular season and high temperature events are considered as a "high" risk to their shrimp farming. It is likely that changing in temperature is the most important factors and have significant impacts to the shrimp farming.

Temperature, rainfall and sea level rise change were observed a steady increase rate and predicted that these climatic events would continue changing substantially to the year of 2100 at both local and global levels. In the Mekong Delta region, temperature could increase to about 1^{o}C in 2050 and 2^{o}C in 2100. Similarly, rainfall could also increase to 0.8% in 2050 and 1.5% in 2100. Sea level rise also increase to 30cm in 2050 and 75 cm in 2100 (Table 55). Hence, recommended adaptation measures for the future should pay attention to predicted climate change, so that adaptation measures are more reliable and realistic.

Table 55: Climate change relative to 1980 – 1999 in the Mekong Delta (medium scenario)

Category	Year								
	2020	2030	2040	2050	2060	2070	2080	2090	2100
Temperature (^{o}C)	0.4	0.6	0.8	**1.0**	1.3	1.6	1.6	1.9	**2.0**
Rainfall (%)	0.3	0.4	0.6	**0.8**	1.0	1.1	1.2	1.4	**1.5**
Sea level rise (cm)	12	17	23	**30**	37	46	54	64	**75**

Source: MORE (2009)

A Strength – Weakness – Opportunity – Thread analysis (SWOT) was also done to identify each factor in the SWOT matrix. Multi-cropping: shrimp and rice or polyculture is one of the positive impact from sea level rise or other climate events make salinity increase. Salt water intrusion has negative impacts to rice farming, but it is an opportunity for farmers to diversify into multi-cropping of rice and shrimp culture. In areas where source of water is largely freshwater in the raining season and brackish water during the dry season, farmers can farm shrimp during the dry season and rice crop (possibly together with shrimp) in the wet season. Rice farming is much more profitable than rice farming

Table 56: SWOT analysis in shrimp farming in the Mekong Delta

Strength	**Weakness**
– "Food basket" of Vietnam – Farmers experience on climate change	– Awareness of climate change – Support from the government: technical and financial – Education level – Household economic: almost poor
Oppertunity	**Thread**
– Multi-cropping of rice and shrimp culture:	– Impacts of climate change: more frequency

shrimp only or shrimp – rice integrated – Polyculture: shrimp with mud crap or fish – Association or cooperative member to solve local conflicts and better support – Conservation and wide use of natural resources: release shrimp post larvae into the wild environment to enhance the shrimp stock – Goverment and NGOs interested	and extreme negative impacts – Decline in mangrove coverage (shrimp farming and other activities) – Decline in biodiversity – Diseases bloom – Pollution – Decrease in household's economic

The second important opportunity is that farmers should be a member of a club, association or cooperative. Local authorities should establish club/association/cooperative, local extension officers and head of local authorities are the key players to help farmers in terms of technical support (training, advise on crop calendar, treatment etc.) and other support such as credit and noticing/transferring policies related to climate change.

A typical extensive or improved extensive shrimp models in the Mekong Delta is a pond that there is a ditch around the farm/pond and inside the farm/pond. The platform can be bare land, wild grass, rice (Figure 24) or forest called "shrimp – forest" model. This "shrimp – forest" model can be extensive or improved extensive, but the ownership of land is almost the government, farmers hire the land for a quite long period of time (over 25 years). This model is likely a "co-management" model supported by the government to protect mangrove from clearance. Farmers are permitted to farm only in a certain areas: usually 30% of the land area, the remaining area are natural forest (Figure 48).

Typical extensive model

Shrimp – forest model

Figure 48: Extensive model

7.2. Shrimp farmer

Small-scale shrimp farming in the Mekong Delta such as extensive and improved extensive models is highly vulnerable to climate change as the region is located on the low lying and close to the coast. The area is also susceptible to tidal surge, sea level rise and flooding. Moreover, temperature change is also important factors affecting the farming practice. All the climate changes would contribute to loosing yield/profit and influencing their lives.

In fact, farmers have been living with the change in weather patterns and developed mechanisms to cope with climate change, but they are not prepared for quick changes in seasonality or extreme climate events, leading to decline in productivity and profit. As a result, they are more vulnerable due to lack of money and capacity to adapt. Small-scale shrimp farmers in the Mekong Delta should intensify their farming in a small area of their farm to improve productivity/profit, particularly to cope with climate change and limited reliance on the nature. This is considered only way for farmers to offset climate change. Here are several recommended shrimp models for farmers to improve productivity/profit under climate change impacts.

Model 1: Improved extensive with nursing on farm model:

Generally, farmers stock directly post larvae of shrimp from the local hatchery into their farming pond at PL15 with the size of 1.2 – 1.3cm. This size is relatively small, therefore the survival rate is quite low due to predators and more vulnerable to diseases. Especially, predators in extensive farming systems are quite common such as fish (gobid), amphibian and reptiles. Hence there is a need to nurse post larvae (PL15) to a relatively large size of 5 – 10cm (about 25 – 40 nursery days) in a small area, and then release into the extensive pond. This can help to increase productivity and profit.

In the recommended model, there is a small pond (A1) in a farm. The area of pond A1 is about 10% of a farm area and used for nursery post larvae purposes. Here are requirement for pond A1 as follows:

- Water level: 1.2 – 1.5m
- Two sluice gates (in and out)
- Use of nylon sheet lining underneath the bottom of the pond to prevent water lost

The nursery pond (A1) is used for post larvae nursery (black tiger) in the dry season and stored freshwater in the wet season. The A1 pond can be used to culture fish during the wet season such as snakeskin gourami (*Trichogaster pectoralis*) or tilapia for likelihood diversification to improve household income.

The extensive pond (A2: 90% area) with ditch around (Figure 49). Water level requirement is over 1.2 – 1.5m in the ditch and about 0.5 – 1.0m in the platform. The wall of the ditch should be at least 2 m wide and 0.5m higher the maximum water level. This can protect their farming system from climate change such as storm or flooding.

Operation: post larvae of shrimp is nursery in the A1 pond with a density of 10 – 20 indi/m^2, with the support of aeration (10 – 12 paddle/2,000m^2), feeding by commercial feed, duration nursery: 25 – 40 days to reach 5 – 10cm (2 – 5g), then transferring to improved extensive pond (A2) with the socking rate of 1 – 2 ind/m^2. A new nursery crop can be implemented.

In addition, marine mud crap can be nursery in the extensive pond (A2) by hapas with 200 – 300ind/m^2. After 7 – 10 day nursing, crab is released with a density of 0.1 – 0.2 ind/m^2. Moreover, other species can be considered such as milkfish, barramundi, giant freshwater prawn, snakeskin gourami and tilapia. Rice crop can be used during the wet season with rice species (*Một bụi đỏ*) can tolerate with saline water.

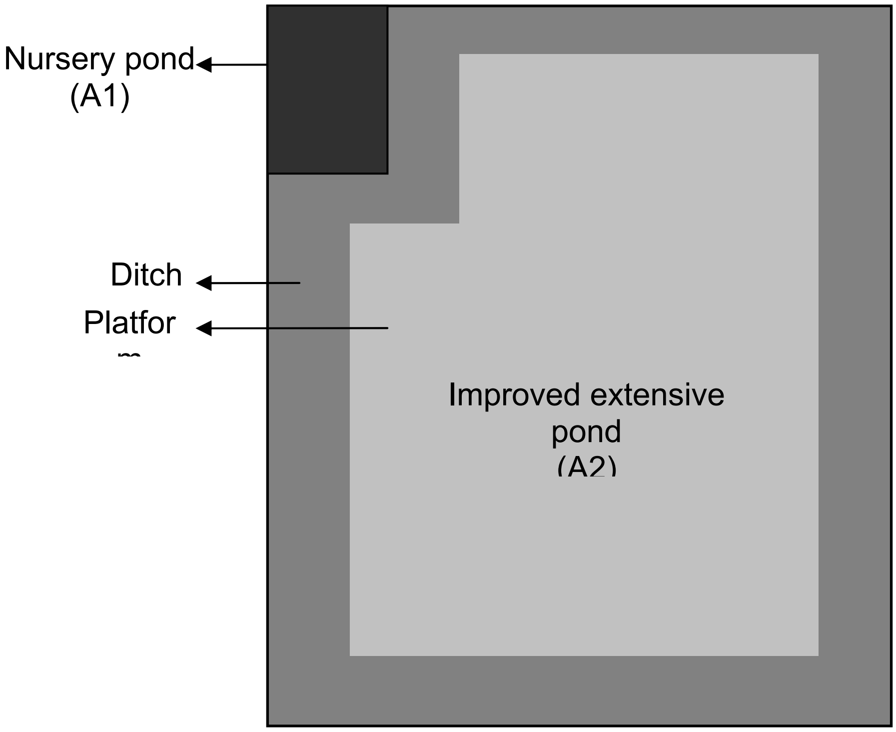

Figure 49: Improved extensive with nursing on farm model

This recommended model is simple and applicable. This model has been implemented as pilot study in Cà Mau in "shrimp – forest" model. Local farmers and authorities appreciate the "Improved extensive with nursing on farm" model and hopely can become wide use in the near future.

Model 2: Shrimp farming with multi-models (improved extensive to intensive)

A farm is divided into 3 ponds (Figure 50):

- Intensive pond (B1): area of B1 pond is about 10% of a farm, used for intensive farming. Aeration (20 paddles/2,000m^2).
- Semi-intensive (B2): area of B2 pond is about 20% of a farm, used for semi-intensive farming. Aeration (10 paddles/2,000m^2)
- Improved extensive pond (B3): area of B3 pond is 70% of a farm, used for improved extensive farming.

Operation: water was transferred from the reservoir to B1 pond and B2 pond and finally to B3 pond. Post larvae (PL15) from the hatchery is stocked with a density of 50 – 60 indi/m^2 for about 40 – 50 days, then transferred to B2 pond with 10 – 20 indi/m^2 and nursery for next 40 – 50 days to reach assize of 8 – 10 g/ind, then transferred to B3 pond (1 indi/m^2) for 60 days. At this stage, size of shrimp can reach 25 – 30 g/ind and proceed harvesting market size individuals (25 – 30 g/ind) by trap.

Pond requirements and diversification of species culture are similar with Model 1. For example, milkfish, giant freshwater prawn, snakeskin gourami and tilapia are important candidates for species diversification to improve productivity.

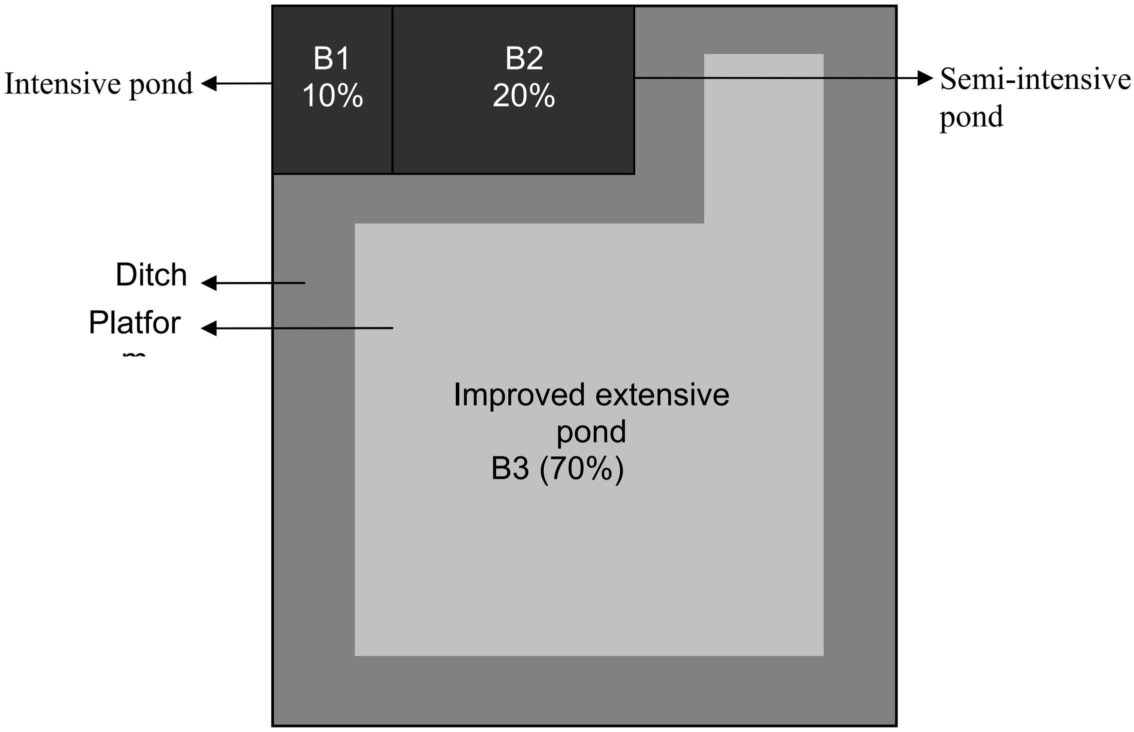

Figure 50: Shrimp farming with multi-models

Model 3: Improved extensive – semi-intensive

A farm is divided into 2 ponds (**Error! Reference source not found.**):

- Semi-intensive pond (C1): area of C1 pond is about 30% of a farm (not exceed 0.4ha, used for semi-intensive farming. Aeration (12 paddles/2,000m^2).

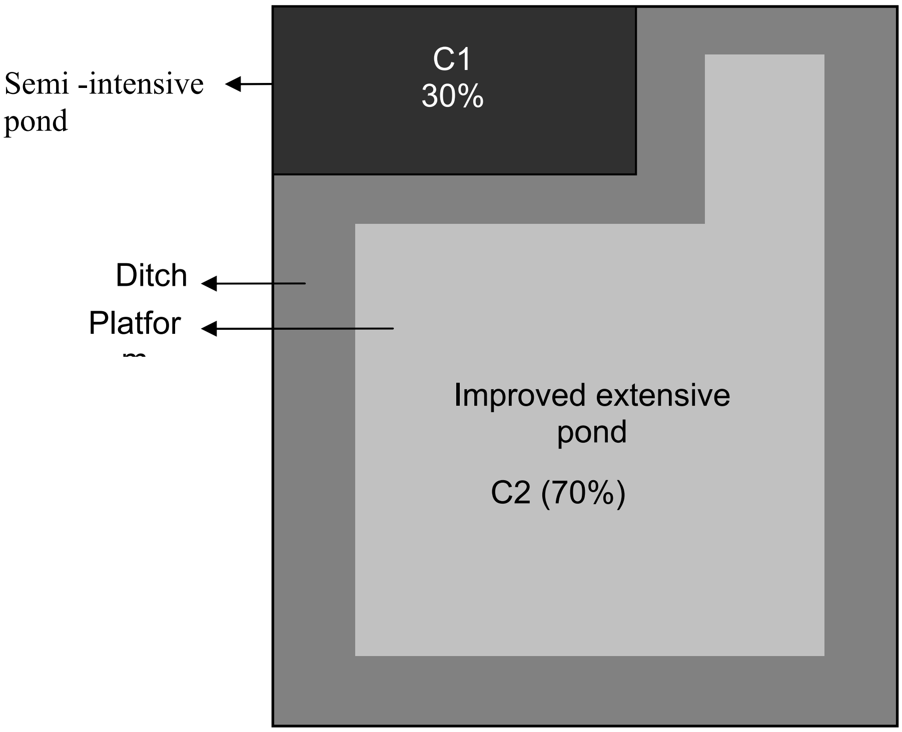

Figure 51: Improved extensive – semi-intensive

Operation: Post larvae (PL15) from the hatchery is stocked in the semi-intensive pond (C1) with a density of 25 – 30 indi/m^2 for about 30 – 45 days, then transferred to extensive pond (C2) with a density of 1 – 2 indi/m^2. The remaining post larvae in the C2 pond (10 – 20 indi/m^2) is continued culturing until harvest. In addition, rice can be used to culture during the wet season to improve the environment.

Pond requirements and diversification of species culture are similar with Model 1. For example, milkfish, giant freshwater prawn, snakeskin gourami and tilapia are important candidates for species diversification to improve productivity.

Model 4: Improved extensive – semi-intensive recirculation system

A farm is divided into 3 ponds (Figure 52):

- Semi-intensive pond (D1): area of D1 pond is about 30% of a farm, used for semi-intensive farming. Aeration (15 paddles/2,000m^2).
- Fish culture pond (D2): area of D1 pond is about 10% of a farm, used to culture fish such as red tilapia to improve water quality (waste treatment purpose).
- Improved extensive (D3): area of D3 pond is 60% of a farm, used for extensive farming.

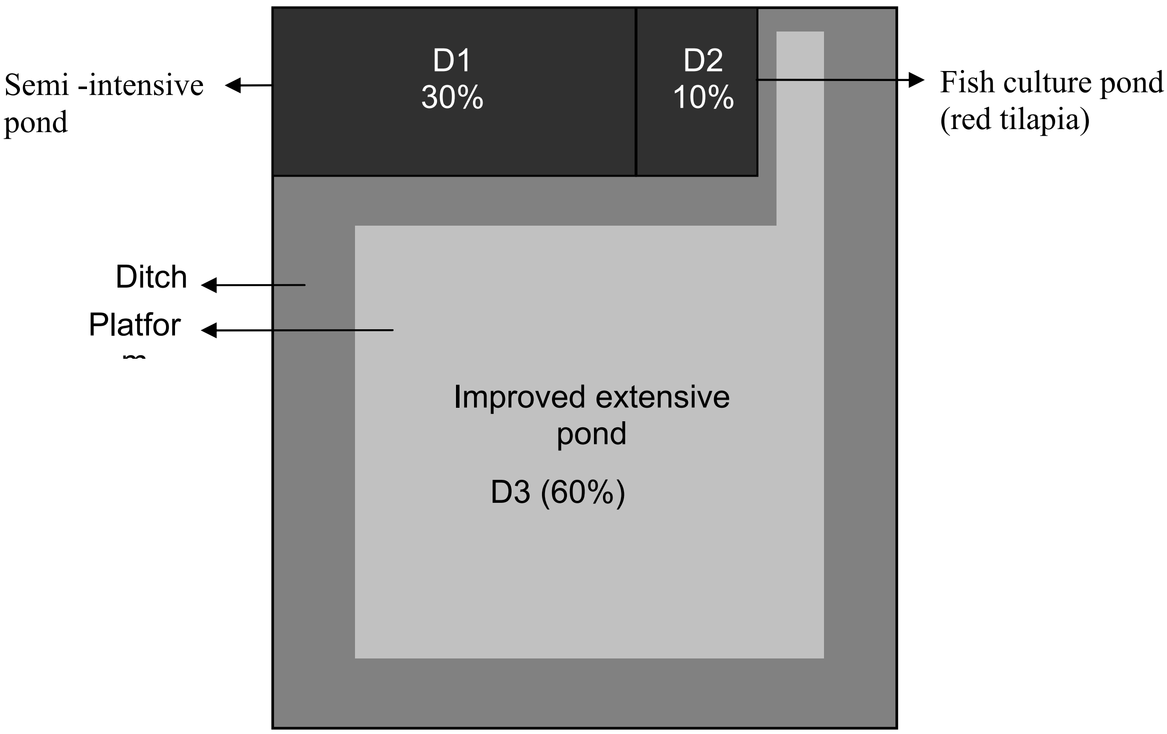

Figure 52: Improved extensive – semi-intensive re-circling model

Operation: Post larvae (PL15) from the hatchery is stocked in the semi-intensive pond (D1) with a density of 10 – 20 ind/m^2 for black tiger shrimp or 35 – 40 indi/m^2 for white leg shrimp. Waste water from pond D1 is transferred to pond D2. Red tilapia is cultured in pond D2 with the density of 2 – 5 ind/m^2. Red tilapia and phytoplankton will absorb waste and other nutrition. Then water from D2 is transferred to pond extensive pond (D3) and continues to improve water quality in pond D3. Finally, water in pond D3 is pumped into semi-intensive pond (D1) about 1- 2 times per week.

This model has advantage by diversification of species and controlling water quality (recirculation). Pond requirements are similar with Model 1.

Model 5: Improved extensive and semi-intensive with no water change:

A farm is divided into 3 ponds (Figure 53):

- Semi-intensive pond (E1): area of E1 pond is about 20% of a farm, used for semi-intensive farming. Aeration (15 paddles/2,000m^2).
- Fish culture pond (E2): area of E2 pond is about 10% of a farm, used for nursery. Aeration (12 paddles/2,000m^2).
- Improved extensive (E3): area of E3 pond is 70% of a farm, used for extensive farming.

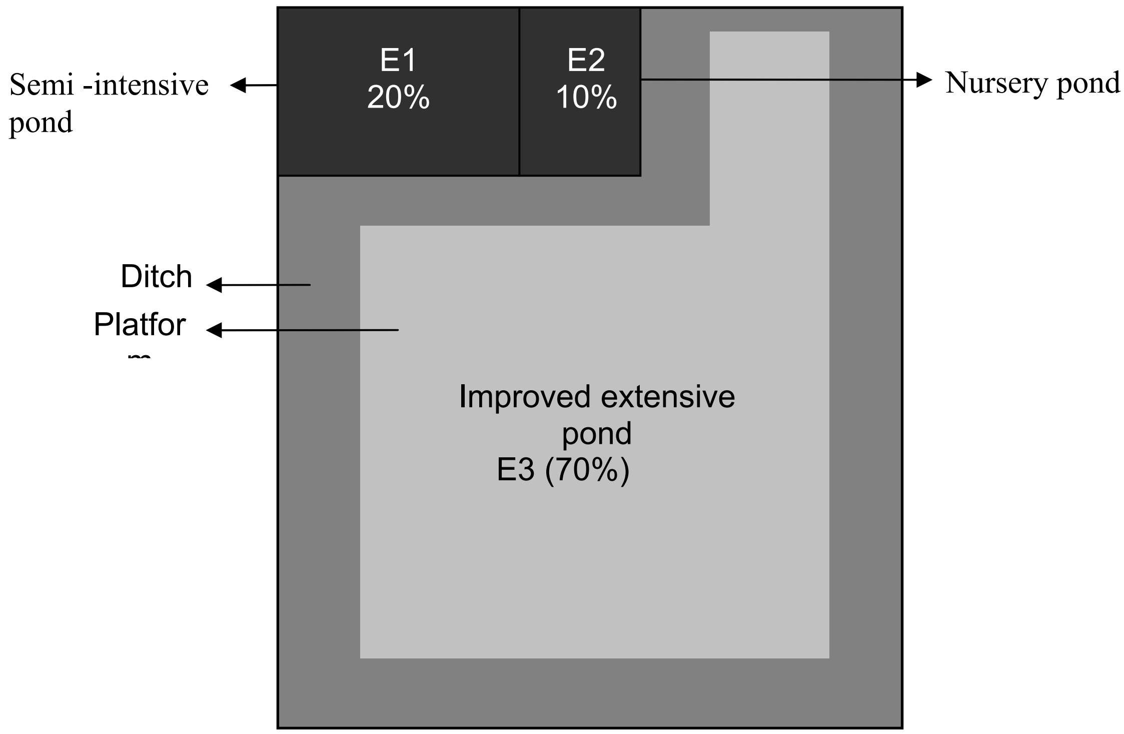

Figure 53: Improved extensive and semi-intensive with no water change model

Operation (E1): Post larvae (PL15) are stocked in the semi-intensive pond (E1) with a density of 15 – 20 ind/m^2 for black tiger shrimp or 35 – 45 indi/m^2 for white leg shrimp with no change water outside the farm. Water is supplemented from the improved extensive pond (E3) by pumping.

Operation (E2 & E3): post larvae of shrimp is nursery in the E2 pond with a density of 10 – 20 indi/m^2, with the support of aeration (10 – 12 paddle/2,000m^2), feeding by commercial feed, duration nursery: 25 – 40 days to reach 5 – 10cm (2 – 5g), then transferring to improved extensive pond (E3) with the stocking rate of 1 – 2 ind/m^2. A new nursery crop can be implemented.

For all recommended models above, rice cultivate in the platform part should be considered during the raining season in order to improve water environment. Rice species (*Một bụi đỏ*) is a important species that can tolerate with saline water and local people has been planted. The nursery ponds can act as reservoir to store freshwater volume and supplement to decrease saline water.

In addition, other economic species are also considered to stock together with shrimp such as milkfish, barramundi, giant freshwater prawn, snakeskin gourami, tilapia etc. to improve income.

Moreover, some local fruit trees or vegetables can be planted in the pond bank to improve farmers' income such as salad, water morning glory, bitter and water melon, bean, blue dragon fruit etc.

Strategies to increase local farmer's resilience to climate change:

Climate change has been happening and impacting local farmers' both shrimp farming and other agricultural activities. There are a number of strategies to increase local farmer's resilience to climate change as follows:

- Applying sustainable aquaculture practices;
- Diversifying farmers' income and food production reduces their dependence on monocultures and spreads the risk of yield and income loss;
- Diversification more resistant species that can tolerate the predicted future climate change;
- Increasing the efficient use of natural resources such as water, feed, and energy increases farmers' productivity in the long run and in a sustainable way;
- Building farmers' capacity through providing access to information and knowledge empowers them to take appropriate action and make informed decisions;
- Building partnerships between different public and private actors helps farmers to benefit from improved framework conditions to cope with climate change.

Building farmer resilience to climate change:

The farmer needs to make their decision to resist climate change or to accept climate change and find ways to live with the consequences. For example, rainfall and flooding or sea level is predicted to increase in the future: for example rainfall in the Mekong Delta could be increase by 0.8% in 2050 (MORE, 2009), to resist this impact the farmer can resist flooding by strengthening and increasing the height of the perimeter dikes; to live with flooding, the farmer can purchase nets that are deployed on the top of the dykes so that when a flood occurs, the shrimp and fish remain in the ponds.

The farmer can implement a wide range of adaptation measures on the farm ranging from purchase and use of technology, changes in pond design to changes in production methodology and timing. However, small scale farmers do not have the financial resources to undertake many of the potential adaptation measures. Therefore it is important to assist the farmers now to become more profitable so that they can cope with the stronger and more unpredictable weather conditions and afford make the recommended adaptation measures.

Farmers should try to improve profitability by reduction in operation costs or more feeding that is proportional to profitable rates. Moreover, selection of high value species culture together with shrimp (integrated) also considered to improve profit. Some key candidates are milkfish, barramundi, giant freshwater prawn, snakeskin gourami, tilapia etc.

Farmers can improve their income/profit by plating some local fruit trees or vegetables in the pond bank such as salad, water morning glory, bitter and water melon, bean, blue dragon fruit etc.

Improvement of technical and management techniques in shrimp farming:

Farmers have to improve their technical and management in shrimp farming by communicating and exchanging experience with other farmers, technical persons or scientists. In addition, farmers should have manuals on shrimp farming for reference to gradually improve their techniques.

Strengthening perimeter dyke:

It is predicted that sea level could increase at least 30cm by 2050 in the Mekong Delta and 75cm by 2100 (MORE, 2009). When sea level rise will be 65cm, about 12.8% of the Mekong Delta will be flooded. In this case, the coastal areas of the Mekong Delta are more prone to storm surge and will lead to high tides. Hence, the dykes (farm, sea, river) need heightened and strengthened in order to prevent shrimp and fish escape from the pond during intense rainfall and storm surge or other extreme weather events. It is recommended that height of the dyke should be strengthened and increased about 30cm more over the top of the bank. The estimated cost for this is about 50,000 VND per meter length. There need to be loans or preferably incentives made available for farmers to strengthen their perimeter dyke.

Purchase and use of equipment:

Some equipments are important in shrimp farming such as water pump, waste pump, aerators. These equipments can help increase/maintain in pond depth, water exchange, temperature fluctuations, oxygen dissolved levels etc. The additional costs should be considered from their own budget or loans from the local banks.

7.3. Science and Technology

Scientific research and technology development can play a strong role to support farmers in developing new adaptation measures to predicted future climate change as well as developing standardized methodology for assessing socio-economic vulnerability of communities and culture systems and developing adaptation measures.

Pond design

Research should focus on pond design by including a nursery area will increase shrimp survival and juvenile quality. Institutes and Universities should provide guidance for farmers for improving pond design including a semi-intensive or intensive shrimp production area within the pond and increase shrimp and pond productivity by recycling nutrients.

Enhancement of pond productivity:

Research should focus on:

- Conduct pilot researches to test efficiency of five recommended farming models above under impacts of climate change. Determine criteria to apply for each model. This can help farmers to choose appropriate farming models.
- Select new species (fish or crab) to integrate with shrimp farming (polyculture) to improve household's income. It is also necessary to determine the proportion among species for stocking.
- Select new rice species that can tolerate with saline water and produce higher productivity.
- Recommended effective pest and disease controls, especially in the small scale farming.
- Training: improve techniques of fertilization organic or inorganic fertilizer to stimulate the plankton. It is necessary to determine type of fertilizer and appropriate stocking rates.
- Improve efficient water use: recirculation or no exchange of water systems.
- Implement zoning for shrimp farming by GIS analysis. It is necessary to determine appropriate farming levels in term of type, location and area of farming, contributing for sustainable development.

There is a need to prepare proposals and submitted to the government or other donors for funding. The results of the studies will help farmers to improve their productivity and to build farmer resilience to climate change.

Breeding:

Research should focus on:

- Domestication of shrimp that can support broodstock for the hatcheries and limit reliance of broodstock from the wild.
- Select species or trains that can tolerate with temperature shocks, other irregular factors and better growth performance.
- Select species or trains that can produce higher yield per unit of area or shorten production cycles.

Aquaculture zoning:

Research on:

- GIS tools and analysis should be considered to plan for sustainable levels of aquaculture development: identify the most vulnerable area or suitable for aquaculture development, area for each farming model *etc*.
- Conduct stakeholder meetings for discussion and agreement before implementation.

Strengthening participatory water management in shrimp farming:

The fact shows that water management is a key issue in shrimp farming as waste water from farming system and water supply is not separated. As a result, a farm/pond infected with disease and lost production can also cause other close farms infect by exchanging water. This leads to conflict among farmers.

Under support of the Mekong River Commission (MRC) from 2006 – 2010, Research Institute for Aquaculture 2 was developed a participatory water management model in shrimp/rice farming in Sóc Trăng province (next to Bạc Liêu province) to solve the problem above. This model was highly appreciated by both local farmers and local authorities.

The main objective of the project was "coordinated and participatory management by aquatic resource managers contributes to improved household productivity, economics and environmental sustainability from shrimp culture-dependent households" and "authorities, and line agencies at the district and commune level have improved capacity to manage water resources jointly with farmers' groups and diversify livelihoods". There is a wide range of stakeholders in the model (Figure 54).

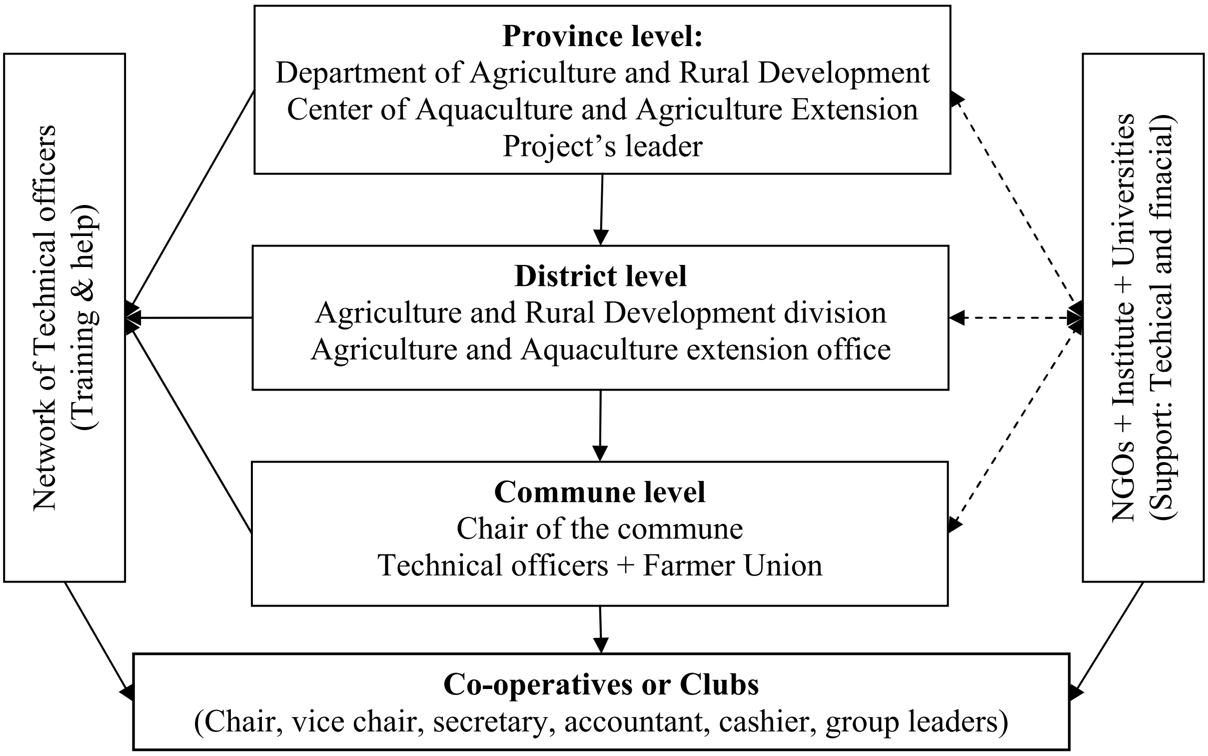

Figure 54: Structure of participatory water management model in shrimp/rice farming

An agreement (regulations) of each co-operative or club is prepared, agreed by all members and released to implement. All members are asked to comply with this agreement. There are some key topics such as exchange water with the same time to prevent disease infection from each other, do not let water infected with disease from their farm/pond out to the public water supply etc.

Shrimp farmers as member of co-operative or club and technical persons (officers) are trained regularly in shrimp culture techniques. Moreover, other training are also conducted such as alternate livelihoods, rice farming, organization and financial and communication skills, low-cost water quality monitoring and management and study tour to exchange their experience among co-operator or club.

Low-cost water quality monitoring equipments were provided to each subgroup and communes' staffs to monitor their farming system and also water supply. So that they can decide whether exchange water and they also inform the status of water quality supply to other farmers.

There is a need to establish co-operative or clubs or propose a new model to help farmers improve their productivity in shrimp farming. Moreover, training or support from the government to the farmers are easier and more efficient.

7.4. Institutions

Local authorities play an important role to support farmers in developing new adaptation measures or implemented adaptation measures. This is because, farmers cannot act alone and therefore should be assisted by potential adaptation measures developed through science and technology and through measures implemented by local and central government institutions. Therefore, local authorities and central government should pay attention or mainstream the strategies for climate change into the national strategies for adaptation and identify the most vulnerable aquaculture systems and plan appropriately. It is important to assist farmers now to become more profitable so that they can cope with the stronger and more unpredictable weather conditions. Some key issues of small –scale shrimp farming should be considered as follows:

Increase in farmers' awareness about the impacts of climate change:

Training should be implemented by appropriate organizations to increase farmers' awareness about the impacts of climate change. The training should repeat regularly. Moreover, impacts of climate change can notify or educate in schools for younger people. In addition, posters about the impacts of climate change should be prepared and placed in public areas. This can assist farmers increase awareness and try to plan or find appropriate solutions by themselves.

Strengthening technical and management techniques of shrimp farming for farmers:

It is necessary to provide manuals on shrimp farming to farmers under impacts of climate change such as pond design and construction, shrimp farming models, pond preparation (liming, eradication of predators and competitors, fertilization, aeration), stocking, calendar crop, nursing and feeding, water quality management *etc*.

Providing weather information and advice:

Weather information at present and forecast should be informed regularly in terms of accurate and timing. So that farmers can assess the provided information and make their decision for the next crop appropriately.

Even though general weather information is also informed in the mass media such as TV station and radio, it is necessary to give also recommendations for farmers about shrimp farming techniques to resist the climate change.

Network of aquaculture extension officer:

It is very important to establish networks of aquaculture extension officers from provincial to local levels. Officers in the network act as technical persons in shrimp farming, they are the key persons to assist shrimp farmers, particularly in diseases bloom, so that they can give appropriate advice to deal with each problem.

Credit support:

Local authorities should have credit programmes or locate fund to help farmers living or adaptive to climate change. Local bank such as Agricultural and Rural Development Bank or Policy Bank are the key banks to help farmers more resilient to climate change.

Classification of poor for farmers:

There is a need to classify farmers into different levels of poor such as poorest, poor, near-poor, medium, and rich. This can help the most vulnerable group of people under climate change impacts so that any support should focus on this group first and other groups later.

Market price:

Stable market prices can be achieved by encouraging processors to locate close by and for the farmers to agree yearly contract price to supply the processors. Higher prices can be achieved by reducing the number of fish trader transactions between the farmer and the retail outlet.

Mangrove protection and planting:

Mangrove wetlands are important for the whole ecosystem as they support to the aquatic and terrestrial species and provide many benefits to our society. Wetlands are home to fish, wildlife, other animals as well as flora. In addition, wetland vegetation especially mangrove in coastal areas impede the movement of flood waters or storms and distribute them more slowly over floodplains, so that they can help reducing erosion and flooding and protect agricultural crops and human being from natural disasters.

Moreover, wetlands provide the conditions needed for the removal of nutrient from human inputs (aquaculture and sewage). Therefore, they also reduce environmental problems, such as algal blooms, dead zones, and fish kills, that are generally associated with excess nutrient loadings. In addition, wetlands store carbon within their live and preserved (peat) plant biomass instead of releasing it to the atmosphere as carbon dioxide, a greenhouse gas affecting global climates.

There were a total of 276,300 ha of forest in the Mekong Delta, covering 6.82% of the region. Most of the forest are planted forest (78.14%), natural forest accounts for only 21.86% and distributes mainly in Kiên Giang and Cà Mau provinces (Figure 55).

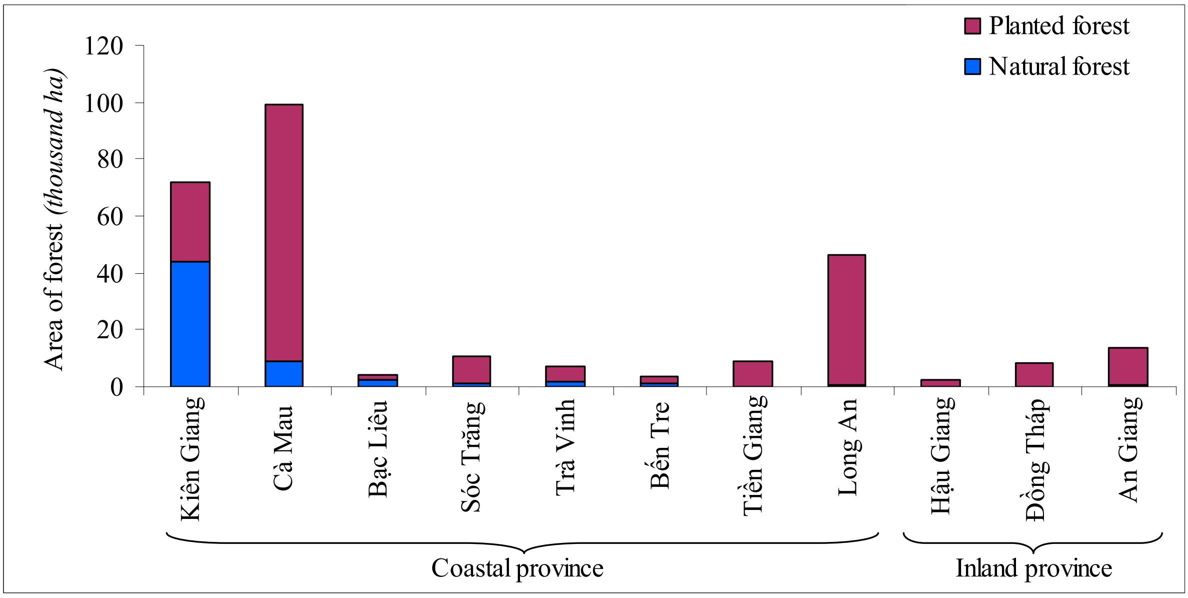

Figure 55: Area of forest in the Mekong Delta in 2009
Source: GSO (2011)

However, coastal forest area of the Mekong Delta has been declined significantly due to many reasons such as clearance of mangrove for shrimp farming. It is necessary to plant mangrove to prevent extreme events such storms and improve water quality. Research center of mangrove in Cà Mau can prepare proposals for this issue.

Water monitoring programme:

RIA2 has been established a network of water monitoring station in the Mekong Delta for about 6 six years under support of the government to monitor and assess the status of water quality for aquaculture purpose. Therefore, local authorities should associate with RIA2 to establish a new monitoring station together with existing RIA2's station to monitor regularly and inform local farmers about the status of water quality. RIA2 can make proposal to submit to province for approval.

Enhancement of shrimp population in the wild:

In reality, all most all black tiger shrimp hatcheries catch broodstock from the wild and do propagation in the hatchery by different techniques. Domestication of shrimp just limits in the experiments at several research centers and institutes, not for commercial purposed. About 123.129 black tiger shrimp broodstock per year were collected in the wild in Cà Mau and distribute to hatcheries in/outside the Mekong Delta (Chau Tai Tao *et al*., 2008).

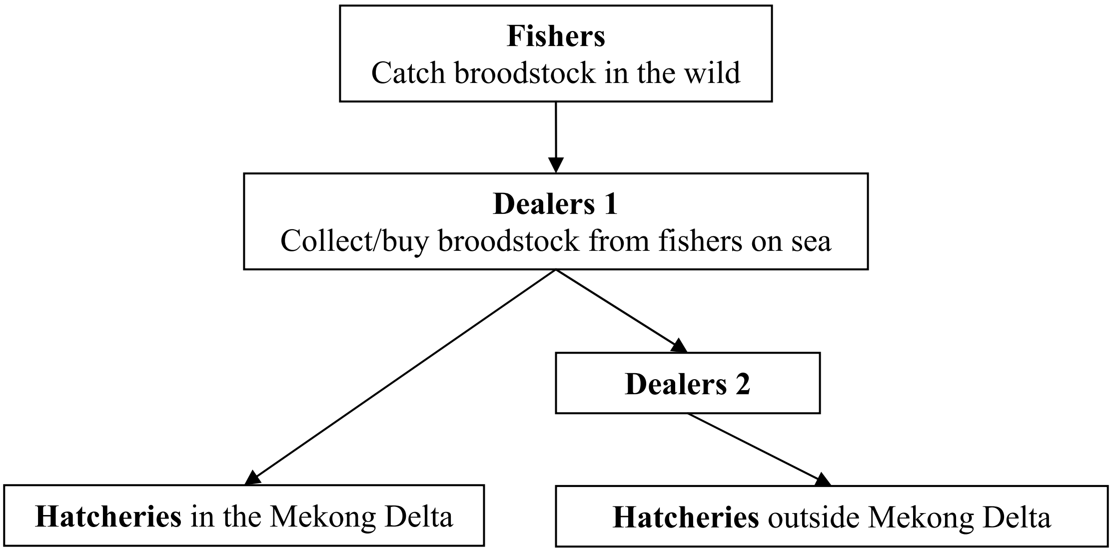

Figure 56: Supply chain of black tiger shrimp broodstock

It is important to also enhance shrimp stock in the wild so that this supports brood stock for the hatchery. To do this, local government should encourage hatcheries contribute to enhance the stock by releasing post larvae into the wild. In the same time, a "shrimp restoration fund" should be established and ask support from local hatcheries to enhance the stock in the wild.

Figure 57: Releasing shrimp event in Cà Mau in 2010

Chapter 8 – Policy Options and Framework

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8.1. Introduction

One of the objectives of the AquaClimate Project is "to develop guidelines for policy measures and decision support tools", which will contribute to an increase in resilience and enhance adaptive capacities of resource-poor, small-scale aquaculture farmers and those dependent on aquatic resource for their livelihoods, to the impacts of climatic change. As aquaculture has multiple sets of stakeholders that have direct and varying interests in (as well as influence on) the sector, and who might benefit or be harmed by an action or policy, it will be important to determine the attitudes and preferences of various interest groups towards the identified/proposed actions and policies. The prioritization of policy options based on stakeholder's perceptions will help in guiding the policy makers to reformulate their strategies to cope with the expected climate change conditions.

The project identified three main groups of stakeholders, which are 1) farmer group, 2) science and technology group, and 3) policy and institution group. The weighting of policy options of each group was determined by using Analytical Hierarchy Process (AHP) (Saaty, 1977) as a tool and then the hierarchy (ranking) of decision elements was developed (Saaty, 1990). AHP provides the decision makers with a comprehensive framework for solving problems particularly when they make multi-criteria and multi-actors decisions. The perceptions and purposes can be integrated into an overall synthesis by using AHP (Saaty, 1990).

A trade-off analysis (also called a trade study) is an analytical method or tool for evaluating and comparing system designs based on stakeholder-defined criteria. The stakeholders were asked to investigate alternatives (issues/measures) and to compare and select the best alternative to answer a basis question, which is "Are the solutions that are being suggested as good as possible?". The alternatives (issues/measure) were investigated based on the overall feasibilities, which are:

- Economic feasibility = "Cost-Benefit analysis" of related parties
- Technical feasibility = Ability for new development and new technique evaluation by related parties
- Operational feasibility = Usability (performance, efficiency etc.)

The AHP and trade-off analysis were integrated and used as tools in this project for developing the policy options and framework. For weighting the climate change issues, the stakeholders considered whether the issues were urgent in term of calling for immediate measures or not and while weighting the measures for the respective climate change issues, the stakeholders used "trade-off analysis" as criteria for decision making.

A very important practical application for government would be balancing the allocation of resources for specific purposes and to specific sectors for the purpose of increasing their overall adaptive capacities to manage a broader set of risks (rather than to specific risks) to their livelihoods and security.

During the stakeholder workshop, participants were divided in three groups, which were 1) farmers, 2) science and technology, and 3) policy and institution. After the group discussion about the climate change issues and adaptation measures for each issue was completed, the list of selected urgent issues and their measures were used to develop the AHP questionnaire. Based on the AHP (Saaty, 1990), the pairwise comparisons of the decision-elements (climate issues and measures of each issue) were performed by using a nine-point weighting scale to generate the input data and then the prioritizations of the decision-elements were analyzed. The policy frameworks including the policy options based on the groups of stakeholder's preferences is presented below. The responses of the participants who had a consistency ration of 0.10 or less is considered acceptable and included in the framework.

8.2. Policy framework based on farmer group's prioritizations

The main climate change issues for the farmer group were high temperature (32.0%), storm and typhoon (26.3%), sea level rise (26.2%), and rain fall in dry season (15.5%). The most preferred adaptation measure for farmers to deal with high temperature of water was change surface water (36.2%). Improvement in pond dikes (wider and stronger) was received the highest ranking for storms and typhoons (38.5%) and sea level rise (35.3%). For rainfall in dry season the main adaptation measure was use of lime to adjust water quality (50.4%) (Figure 58).

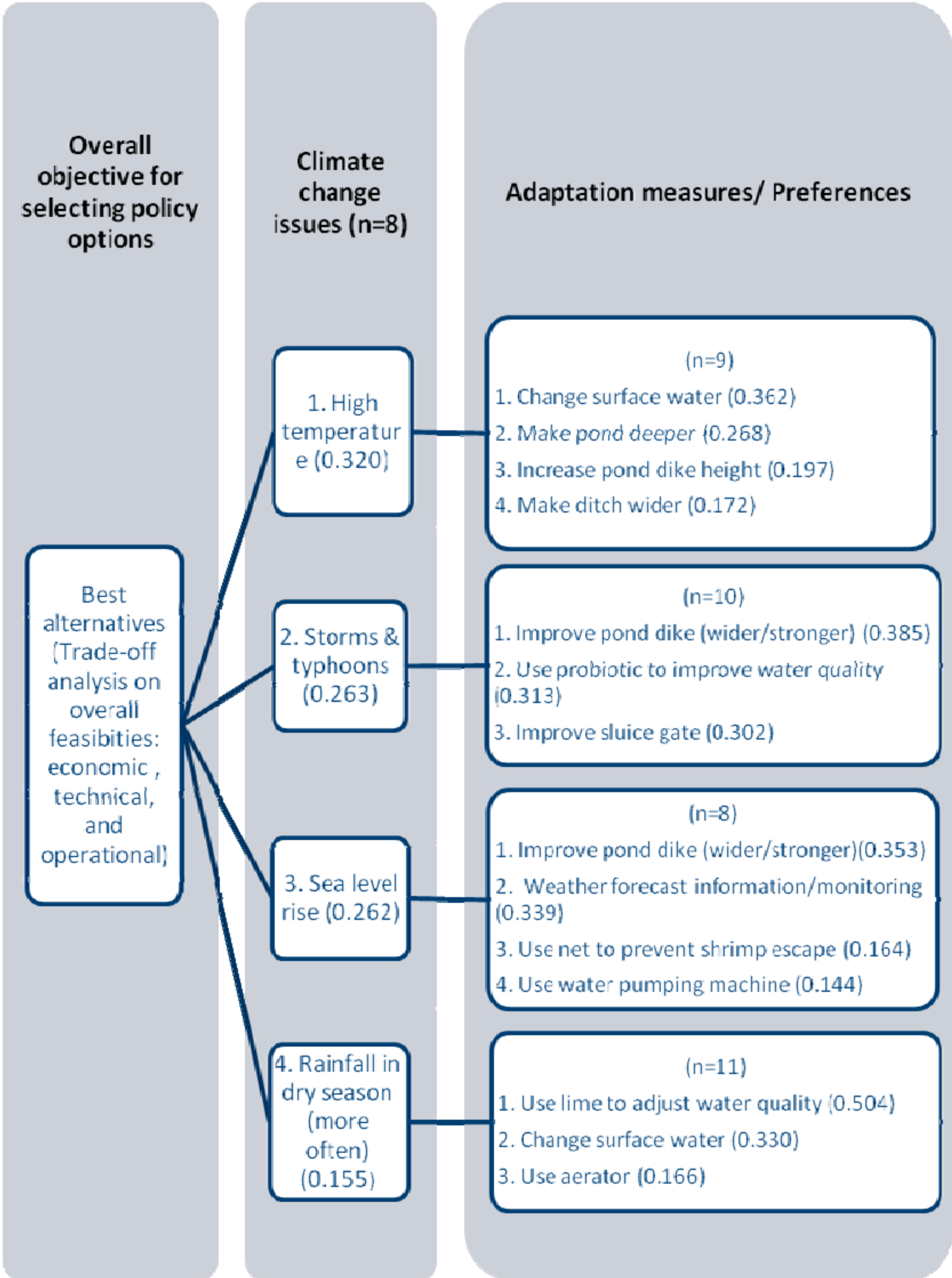

Figure 58: Policy framework based on farmer group's prioritizations

8.3. Policy framework based on science and technology group's prioritizations

The ranking of four main climate change issues perceived by science and technology group were rainfall in dry season (48.4%), storms and typhoons (22.7%), temperature rise (16.8%), and sea level rise (12.1%). Best Management Practice (BMP) was preferred by science and technology group as adaptation measure for rainfall in dry season (49.0%) and temperature rise (55.5%). Planning and zoning for rice and shrimp culture (42.1%) was the most preferred adaptation measure for sea level rise. As proposed by science and technology group the adaptation measure for all four climate change issues, a new pond design should be developed such as making pond dike higher and stronger and growing aquatic plant on platform (Figure 59).

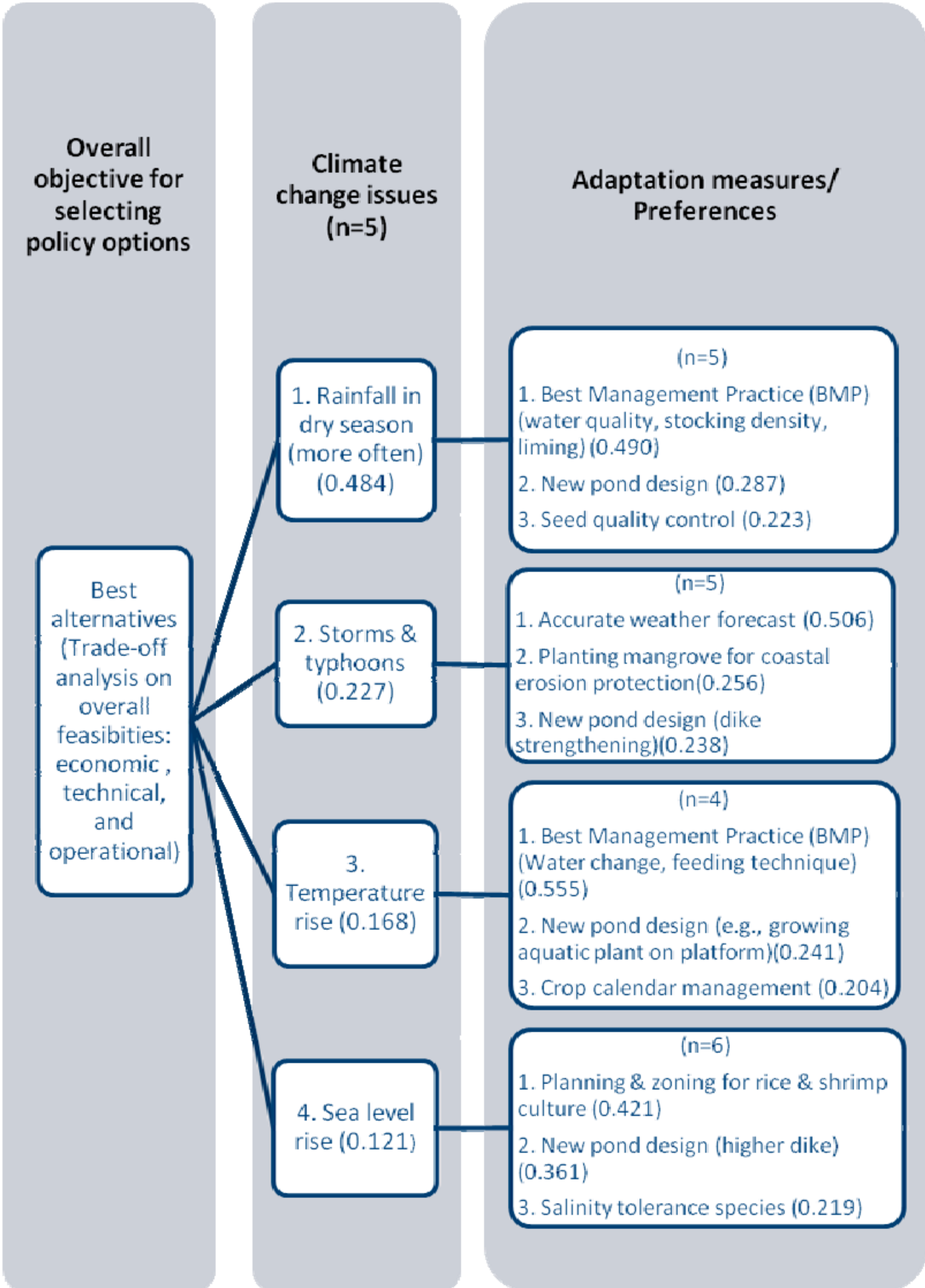

Figure 59: Policy framework based on science and technology group's prioritizations

8.4. Policy framework based on policy and institution group's prioritizations

The policy and institution group discussed and proposed general adaptation measures/ preferences that need for shrimp culture. The most preferred adaptation measure was training of farmers and extension workers (42.9%) followed by more funding for improving infrastructure (dike and sluice gate maintenance) (24.3%), need for standard routines for monitoring shrimp farms (19.5%), and establishing shrimp cooperatives (13.3%) (Figure 60).

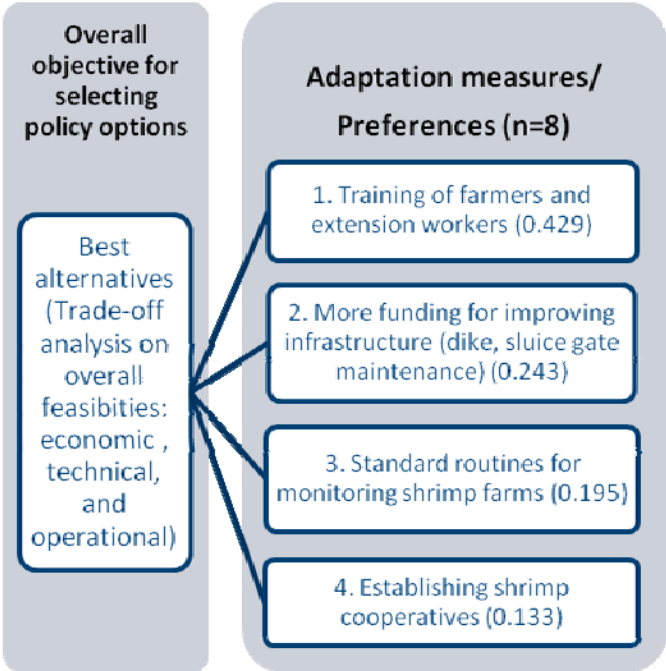

Figure 60: Policy framework based on policy and institution group's prioritizations

Generally, storms and typhoons issue was ranked as the second issue for farmer group and science & technology group. This climate change issue is relatively noticed since storm and typhoon can produce a major loss to the shrimp culture system.

Higher temperature was ranked as the most serious climate change issue by shrimp farmer group while rainfall in dry season was the first rank for science and technology group. The climate change issues should be discussed further among stakeholders in detailed since different levels of stakeholder's preferences based on different experience and expertises (Table 8.1).

Farmer group tended to select the adaptation measures that related to their current farming activities such as change surface water, making pond deeper, etc. On the contrary, science and technology group focused on more sophisticated adaptation measures based on their experiences and academic knowledge. For adaptation measures identified by policy and institution group were related to their roles and responsibilities (training, increase funding, and established standards).

Based on the results obtained, the project recommended an integrated type of policy establishment involving stakeholder's preferences and participation to provide sustainable policy.

8.5. Gender

- Encourage females participate in training courses and receive related documents
- Improve technical and management in shrimp farming for females by organizing study tours in shrimp farming and exchange experiences
- Increase awareness in impacts of climate change
- Provide more alternative likelihood trainings and other supporting programmes

8.6. Key stakeholders and institutions to target

The project will determine farmers and other stakeholders' preferences towards the adaptation and mitigation strategies. As aquaculture has a multiple set of stakeholders that have direct and varying interests in (as well as influence on) the sector, and who might be benefited or harmed by an action or policy, it will be important to determine the attitudes and preferences of various interest groups towards the identified/proposed actions and policies. This would provide a basis for deciding on trade-offs among the various policy options that would give an optimally efficient outcome for society in general and the poor small aquaculture sector in particular.

Climate change issues in Vietnam, particularly in the Mekong Delta become a hot issue and interested by the government as Vietnam is considered one of the most vulnerable to climate change due to low-lying lands and saline intrusions. The National Steering Committee, Executive Board and the NTP-RCC office was established to respond to climate change in Viet Nam (Figure 61).

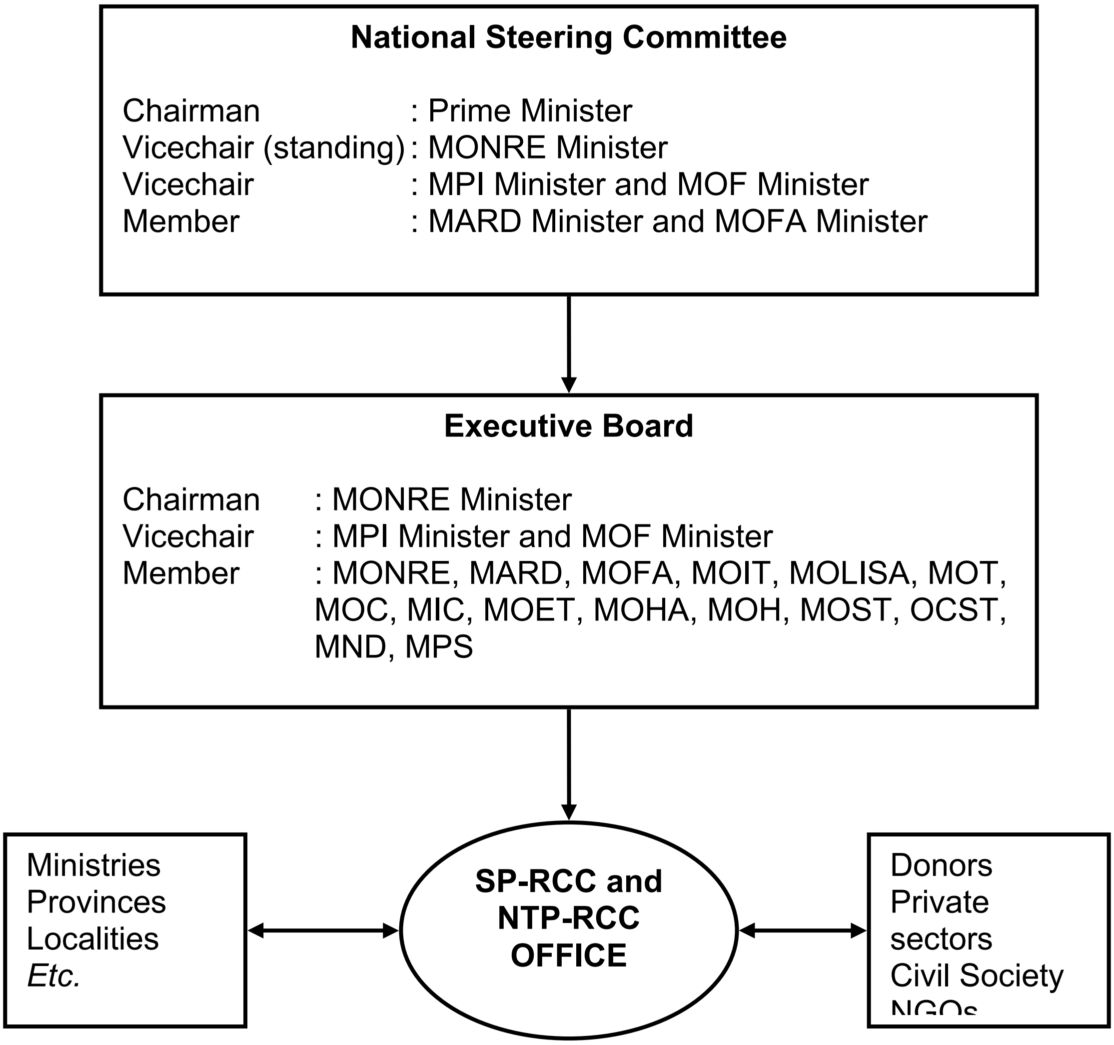

Figure 61: Structure Implementation of NTP-RCC and SP-RCC

At the province level, it is important to develop and improve the organization and management system to respond to climate change, propose priority measures to effectively respond to climate change and sea level rise and develop Action Plans to respond to climate change and sea level rise.

A very important practical application for government would be the balancing of allocation of resources for specific purposes and to specific sectors of the rural economy for the purpose of increasing their overall adaptive capacities to manage a broader set of risks (rather than to specific risks) to their livelihoods and security.

Summary of existing policy and institution on climate change

- National Target Program to Respond to Climate Change (NTP-RCC) was approved on the 2nd December 2008 by Prime Minister (No 158/2008/QD-TTg). The strategic objectives of NTP-RCC are to assess climate change impacts on sectors and regions in specific periods and to develop feasible action plans to effectively respond to climate change in the short term and long term to ensure 5 sustainable development of Vietnam, to take opportunities to develop towards a low-carbon economy, and to join the international community's efforts in mitigating climate change and protecting the climatic system. The main tasks of NTP-RCC are:
    - To identify the extent of climate change in Vietnam due to global climate change and assess climate change impacts on every sector, area and locality;
    - To identify measures to respond to climate change;
    - To promote scientific and technological activities to establish the scientific and practical basis for climate change response measures;
    - To consolidate and enhance the organizational structure, institutional capacity and the development and implementation of policies to respond to climate change;
    - To enhance public awareness, responsibility and participation, and develop human resources to respond to climate change;
    - To promote international cooperation to obtain external support in response to climate change;
    - To mainstream climate change issues into socio-economic, sectoral and local development strategies, plans and planning;
    - To develop and implement action plans of all ministries, sectors and localities to respond to climate change; to implement projects, and first of all pilots projects to respond to climate change.
- "Climate Change, Sea Level Rise Scenarios for Vietnam" document was released by the Ministry of Natural Resources and Environment (MONRE) in June 2009.
- Action Plans to Respond to Climate Change (APRCC) was released on the 20th December 2010 by the Ministry of Natural Resources and Environment (MONRE).
- Action Plans to Respond to Climate Change (APRCC) was released on the 23rd March 2011 by the Ministry of Agricultural and Rural Development (MARD).
- Eight provinces (Cà Mau, Bạc Liêu, Kiên Giang, Sóc Trăng, Cần Thơ, Hồ Chí Minh, Bến Tre and Quảng Nam were selected to implemented the following tasks:

- Develop and improve the organization and management system to respond to climate change
- Assess the impact of climate change and sea level rise at local level
- Propose priority measures to effectively respond to climate change and sea level rise
- Develop Action Plans to respond to climate change and sea level rise
- Proposal effective models to adapt to climate change and sea level rise in two pilot provinces (Quảng Nam and Bến Tre).

- National Climate Change Strategy (NCCS) was approved on the 5th December 2011 by Prime Minister (No 2139/QD-TTg). Vietnam considers response to climate change is vital and Climate change adaptation and GHG reductions will be implemented simultaneously, adaptation is the priority in the early phase of the strategy implementation. There are some key tasks as follows:
  - Actively respond to natural disaster and monitor climate change impacts
  - Ensure food security and water resources
  - Actively adapt to sea level rise in vulnerable areas
  - Protection and sustainable development of forest, increasing carbon removals and biodiversity conservation
  - Green house gas emission reduction to protect global climate system
  - Strengthen the leading role of the Government in responding to climate change
  - Develop effective community response to climate change
  - Develop scientific and technological advances to respond to climate change
  - Enhance international cooperation and improve national position in negotiations on climate change
  - Diversify financial resources and investments on climate change
- National Action Plan on Climate Change is preparing and will submit to the Prime Minister sometime in 2012 for approval: Adapting to climate change; Reducing greenhouse gas emissions; Strengthening the management system of climate change and complete mechanisms and policies for human resource development; Implementation of activities in scientific and technological foundation for policy development on climate change; Promotion of international cooperation to improve the position and role of Vietnam in the activities on climate change.
- Support Program to Respond to Climate Change (SP-RCC): In order to support the implementation of NTP-RCC, the Government and donors decided to formulate SP-RCC. The main objective of SP-RCC is to promote climate change adaptation activities and GHG reduction, through policy dialogues, to ensure sustainable development in Vietnam in terms of economic, social and environment aspects. SP-RCC is also supporting aid harmonization and coordination for policy related activities, technical and financial assistance provided by Government, donors, NGOs and private organizations for climate change response in Vietnam.

The Ministry of Natural Resources and Environment (MONRE) is assigned to coordinate all activities related to climate change in Viet Nam with the following main tasks:

- Need to mainstream into Government Policy, strategy and Action plan;
- Develop policies, strategies and manage the activities related to climate change in all sectors and localities in Viet Nam;
- Guiding sectors and provinces to set up the Action Plans to deal with climate change;
- Monitoring and evaluation of the progress of implementation of action plans of the sectors and provinces;
- Coordination in Public awareness, Policy dialogues and International cooperation
- To set up Climate Change, sea level rise scenarios for Viet Nam;
- Take leadership in climate change finance by working with donor community, NGOs and private sector. Coordination of CC ODA;

In all provinces and line ministries there is one focal point for climate change activities. The main following tasks of this office are to prepare action plans and coordinate for the implementation of climate change activities in their Provinces/Ministries.

- Set up the sector/provincial action plans and manage the implementation of the climate change activities within sector/provincial areas;
- Integrate the climate change activities into social-economic development;
- Mobilize participation from NGOs, civil society and private sector for implementation climate change activities;

Chapter 9: Conclusions

- Shrimp farming in the Mekong Delta is dominated by small-scale practices in terms of area and production. For example, Cà Mau province contributed about 20% of aquaculture shrimp to the total Mekong Delta and 15% of the nation, especially 91% of the production from the improved extensive model.
- In improved extensive model: shrimp seed stock 1.26 – 2.84 ind/m^2, and also stock fish and crab (poly culture). Most of costs were sediment removal. Yield ranges 133.00 – 159.60kg/ha/season. Total costs estimated about 3.87 – 5.16 million Dong/ha/season and profit estimated about 8.03 – 17.76 million Dong/ha/season.
- Shrimp farming is the most important activities in both provinces in terms of income, accounting for 70.27 – 52.27%. Income from laboring contributes a relative high portion (12%). It indicates that farmers are relative poor and dependent on shrimp farming in terms of food security and employment. In addition, loan is very common in both provinces: 31.68% in Bạc Liêu and 43.00% in Cà Mau.
- Annual mean temperature in the Mekong Delta would increase about 1^oC in 2050 and 1.4 – 2.6^oC in 2100, compared to the average of the period 1980 – 1999. Similarly, sea level was also projected to increase. Sea level may rise about 28 – 33cm by 2050 and about 65 – 100cm by 2100 relative to the baseline period of 1980 – 1999. In addition, annual rainfall in the Mekong Delta would increase about 1 – 2%.
- Local farmers have already observed irregular weather pattern and extreme events for the last decades. There are at least 11 climate change events observed by farmers: Irregular season, Temperature rapid change, High temperature, Low temperature, Typhoon/storm, Heavy rain, Flood from rain, Drought, Water salinity increase, Water salinity decrease, Tidal surge/flood. Moreover, there are 80.31 – 9.45% farmers observed and believe those climate change events are "Likely" and "Almost certain" happening. The farmers stated that most of climate change impacts have negative impacts (74.75%), 20,56% have no consequence and 4.69% have positive impacts. Opportunity to diversify likelihoods into multi-cropping (rice crop in the wet season and shrimp in the dry season) is a typical positive impact from salt intrusion.
- Farmer perceptions of climate change are identified: High temperature, Water level rise, Rainfall in the dry season, Storm and typhoon, and irregular seasonal change. Impacts of each climate change issue as described below:
    - *High temperature*: Feeding rate, Growth performance (moulting), Respiratory and immune system, and Mortality.
    - *Storm and typhoon*: Feeding rate, Pond damage, Loss production, and Mortality.
    - *Sea level rise*: Pond damage, Loss production, and Pond preparation.
    - *Rainfall in the dry season*: Widely water environment change, Feeding rate, Growth performance, and Mortality.
- Farmers stated that "High temperature" is the most important factors influencing their shrimp farming followed by "Storm and typhoon", "Sea level rise", and "Rainfall". Meanwhile, group of Science and Technology claimed that "Rainfall" is the most important due to irregular and unusual weather, followed by "Storm and typhoon", "High temperature", and "Sea level rise".

- Adaptation measures are identified by farmers and have been adapted to climate change. In addition, policy frameworks including the policy options are also recommended by Science and Technology Group. Therefore, the Government should take into account for planning and implementation. The DARD at provincial level play an important role to support and implement identified adaptation measures and policy options to help local farmers adapting faster and more efficient under impacts of climate change. Moreover, Institutes and Universities also should cooperate with DARD to support and implement this mater.

Climate change issues	**Farmer Group**	**Science and Technology Group**
1. High temperature	*Ranking: 1st* – Change surface water: 36.2% – Make pond deeper: 26.8% – Increase dike height: 19.7% – Make ditch wider: 17.2%	*Ranking: 3rd* – Best Management Practice (BMP): 55.5% – New pond design: 24.1% – Crop calendar management: 20.4%
2. Storms & typhoons	*Ranking: 2nd* – Improved pond dike: wider and stronger: 38.5% – Use probiotic to improve water quality: 31.3% – Improve sluice gate: 30.2%	*Ranking: 2nd* – Accurate weather forecast: 50.6% – Planting mangrove for coastal erosion protection: 25.6% – New pond design: dike strengthening: 23.8%
3. Sea level rise	*Ranking: 3rd* – Improve pond dike: wider and stronger: 35.3% – Improve forecast information/ monitoring: 33.9% – Use net to prevent shrimp escape: 16.4% – Use water pumping machine: 14.4%	*Ranking: 4th* – Planning and zoning for rice and shrimp culture: 42.1% – New pond design: 36.1% – Salinity tolerance species: 21.9%
4. Rainfall in the dry season	*Ranking: 4th* – Use lime to adjust water quality: 50.4% – Change water surface: 33.0% – Use aerator: 16.6%	*Ranking: 1st* – Best Management Practice (BMP): 49.0% – New pond design: 28.7% – Seed quality control: 22.3%

- AAPFs' model found that "Respondent household income from all farm activities" is significant impact variable influencing the farming system in both provinces. This is the positive relationship: having more income can increase shrimp farming productivity. For example in Cà Mau, there are 2 variables detected in the AAPFs' model: "Respondent household income from all farm activities" and "Total commercial feed cost". Meanwhile, AAPFs' model in Bạc Liêu detected: "Respondent household income from all farm activities", "Total commercial feed cost", "Height of dyke", "Income from fish", "Total lime cost", "Income from crab".

- Although farmers observed climate change events, Applied Aquaculture Production Function (AAPF) analysis found that none of the climate change variables have been detected in AAPFs' model. It is likely that farmers is applying appropriate adaptation measures and can limit impacts on pond productivities.

- There is a significant relationship between levels of education and shrimp farming productivity. Farmers with more experience and better educated have higher resilience and adaptive capacities. Farmers with better education can apply their knowledge to invest or do a business against climate change better than others.
- AAPF nature for this study can only represent a snapshot picture of Bạc Liêu and Cà Mau shrimp production function in 2009 along with the climate change nature which may have been lasted for more than decades. Time series and panel data of major catfish production inputs to dynamically identify both gradual and sudden impacts on their shrimp production are recommended.
- Adaptive measures for remedying any climate change impact in their shrimp farming activities may have already been incorporated into their way of aquaculture production for long time, especially a gradual climate change impact type; therefore, a simple farmer's perception on climatic change aspects may not capture all of these essences. Integrated major local environmental data to the next analysis is recommended.
- The different mFCR may indicate a problem not only from any climate change impact as the major investigation conducted under the project but also from a common aquaculture farm management practice.
- A study for an optimal species stock combination for improved extensive polyculture farming is strongly recommended to improve all farm operation efficiency and a maximum profit obtained.

Chapter 10: Recommended Action Plan

It is important to remind that the ranking of four main climate change issues perceived by science and technology group were rainfall in dry season (48.4%), storms and typhoons (22.7%), temperature rise (16.8%), and sea level rise (12.1%). Therefore, it is important to consider those climate change issues to recommend action plans for adapting and mitigating the impacts of climate change.

10.1. Short term

- Training of farmers and trainers: Increase awareness of the climate change impacts for local farmers by regular training, posters, workshops, education, mass media and materials on policy/strategy. On the other hand, training of trainers is also necessary to conduct.
- Establish network of aquaculture extension officer: Officers in the network act as technical persons in shrimp farming, they are the key persons to assist shrimp farmers, particularly in diseases bloom on farm, so that they can give appropriate advice to deal with each problem.
- Intensify the farming systems: Small-scale shrimp farmers should intensify their farming in a relatively small area of their farm to improve productivity/profit, particularly to cope with climate change and limited reliance on the nature. This is considered only way for farmers to offset climate change. It is necessary to construct a nursery pond used for nursery post larvae for a short period before stocking/releasing.
- Enhance pond productivity: Researches should review and conduct pilot study to test efficiency of existing farming models and recommend suitable farming models under impacts of climate change. Other aspects should be considered such as optimal rate of species combination (poly culture), pest and disease controls, techniques of fertilization. There is a need to prepare proposals and submitted to the government or other donors for funding.
- New pond design and crop calendar management: Local authorities and Institutes/Universities should support farmers in improvement in new pond design for adapting more efficiency to the impacts of climate change. Planting trees around the pond bank or vegetables, contributing to decrease in temperature and improvement of household income. In addition. Water plants are encouraged to plant in the platform of the farming systems.
- Establish routine monitoring programmes: quality of shrimp seed and water and uses of chemicals should be inspected and monitored regularly, then inform/advise farmers in order for them to decide their crop or farming system to be more appropriate.
- Crop calendar management: It is necessary to recommend about crop calendar management for farmers
- Improve weather forecast information: Weather information at present and forecast should be informed regularly in terms of accurate and timing. Even though general weather information is also informed in the mass media such as TV station and radio, it is necessary to give also recommendations for farmers about shrimp farming techniques to resist the climate change.

- Establish shrimp cooperatives/clubs: Farmers nearby can organize a group as cooperatives or clubs for strengthening participatory water management in shrimp farming under co-management schemes. Representatives from local authorities/unions and NGOs should support for club/cooperatives, especially at the beginning of the establishment.
- Diversify livelihood: it is important for diversifying farmers' income to improve local farmer's resilience to climate change.

10.2. Long term

- Assess and update impacts of climate change scenarios for Vietnam and specific areas. MONRE is assigned to coordinate all activities related to climate change in Viet Nam. Hence this Ministry plays an important role for actively updating climate change scenarios and disseminates related documents for public and related agencies.
- Encourage farmers to apply Good Aquaculture Practices. Government and NGOs should support farmers, especially small scale farmers. There are several existing aquaculture certifications such as BMPs, GAP, Global GAP, ShAD, VietGAP *etc*.
- An ecosystem-based co-management should be applied to aquaculture planning and development. Aquaculture practice should be developed in the context of ecosystem functions and services within the resilience capacity limit and improve human well-being and equity for all stakeholders.
- Select or improve species for more tolerant of climate change: Institutes and Universities can conduct a research to suggest appropriate species for aquaculture under impacts of climate change.
- Plan and zone for aquaculture at sustainable development: GIS tools and analysis should be considered to plan for sustainable levels of aquaculture development: Examine the land use and identify the most vulnerable area or suitable for aquaculture development, area for each farming model.
- Enhance shrimp population in the wild: in fact, almost all hatcheries catch broodstock from the wild. Hence, the hatcheries/processing companies should have a responsibility to enhance wild population of shrimp by releasing regular shrimp seeds into the wild.
- Enhance and protect coastal mangrove areas: mangrove forest plays an important role in protection of coastal areas such as erosion and storm/typhoon. Moreover, mangrove forest can act as a filter in water quality and eutrophication improvement.
- Mainstream into Government Policy, Strategies and Action plans: It is important to mainstream climate change activities into Government Policy, Strategies and Action plans. Also, there is a need for inter-sectorial and inter-governmental cooperation to assess and mitigate the impacts of climate change.
- Allocate more funds for climate change: The Government should allocate more funds to improve farmers' infrastructure, existing irrigation systems, construct coastal dykes and other related activities.
- Identify and secure funding: supports from local, regional, donors, NGOs… should be considered into actions to support local authorities and farmers.

- Establish “New rural development model” as recently approved by the Central Government with the aim at supporting a group of local people under of specific industry such as shrimp farming to improve household’s income and sustainable development.

Reference:

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Annex 1: Generic Project Methodology

1. Project preparation

1.1 Climate Change model and scenario selection

The ability of the model to simulate the present climate conditions is an important consideration taken into account in the selection of GCM to be used in this study. The performance of individual GCMs may differ for individual climate variables as well as for different regions of the world. Typically, GCMs are validated for their ability to reproduce spatial patterns of selected variables and their annual cycles. GCMs are run by a number of research centres. Some differences exist among the models, which result in various climate sensitivities in a range. However, selecting appropriate models is difficult especially when many models are available with different projection results.

WORLDCLIM data set was chosen in favor of the data from the IPCC Distribution center because of the higher resolution data set available in WORLDCLIM that can be readily applied for impact studies. WORLDCLIM provides a number of outputs that have been downscaled from Global Circulation Models at no cost and the database has 400 times higher spatial resolution than previously available surfaces (New et al., 2002). Data is based on interpolated climate surfaces for global land areas in four different spatial resolutions; 30 seconds (about 0.86 km2 at the equator), 2.5 minutes, 5 minutes, and 10 minutes (about 344 km2 at the equator) and can easily be exported to GIS.

Emissions scenarios represent how greenhouse gas (carbon dioxide, methane, nitrous oxide) emissions, and thus the accumulation of greenhouse gases in the atmosphere, might unfold over the next century. The IPCC has developed a suite of emissions scenarios that are widely used to generate climate projections from GCMs. These are reported in the IPCC Special Report on Emissions Scenarios (SRES). The SRES emissions scenarios are based upon the many factors that will determine the future level of GHGs in the atmosphere: population growth, economic development, technological innovation, energy consumption, land-use, agricultural development, and environmental policy.

Scenarios are often based on a combination of expert judgement, extrapolation of trends, international comparisons, and model runs. Historical developments are a good guide for future developments. The scenarios are based on a set of four narrative story lines labelled A1, A2, B1 and B2. The storylines combine two sets of divergent tendencies: one set varies its emphasis between strong economic development and strong environmental protection; the other set between increasing globalization and increasing regionalization. The storylines can be briefly described as in the table below:

Summary of Emission Scenarios

	A1	A2	B1	B2
Economic growth	Very rapid. Converging.	Regionally based. Fragmented and	Converging. Service and	Intermediate economic growth.

		slow	information economy	local solutions
Population growth	Peaks mid century	Continues increasing at same pace	Peaks mid century	Continues increasing slowly
technologies	new and more efficient	technological change more fragmented and slower	clean and resource-efficient technologies	less rapid and more diverse technological change
Regional differences	reduction in regional differences	self-reliance and preservation of local identities	Global solutions	local solutions
Environment			Global environmental solutions	oriented towards environmental protection
Climate			without additional climate initiatives	

Making climate projections for a range of SRES scenarios such as the presently available in Worldclim, A2 and B2 emission scenario families can be one way to consider the uncertainties in emission scenarios. B2 emission scenarios for carbon dioxide emission rates are more than double in A2 scenario as compared to A1B and B2 scenarios towards the end of the century. A2 scenario is the more realistic scenario, particularly after the recent credit crunch and specifically A2a (business as usual) and is the recommended choice. The use of other SRES scenarios (A1B, A2, B1, B2) can be important for assessing future impacts and vulnerability to climate change and also one way of addressing uncertainty. Research efforts are needed to quantify future climate changes scenarios for Southeast Asia under different SRES emission scenarios.

B2 scenario may be a more realistic scenario, particularly after the recent credit crunch and specifically A2a (business as usual) and is the recommended choice. However, use of a range of scenarios may be a better approach to understand the range of possibilities (including the worst and best case scenarios) though this may not always be possible due to time and budget constraints.

1.2 Stakeholder panel purpose, identification and implementation

A major outcome of the project is the on-going dissemination of information and results to stakeholders and managers at all levels within the selected case study areas. These processes were two-way throughout the project period to ensure participation, deliberation, and dialogue based on local knowledge. In order to achieve that, the project established a "stakeholder panel" that was comprised of 8 -10 representatives from key stakeholders such as farmers, community groups, local fisheries departments and policy makers.

The stakeholder panel had a number of roles to play:

- Give inputs on the climate change effects already felt in the aquaculture industry
- Give comments on the implementability of the recommendations
- Give feedback on the socioeconomic effects of the recommendations

There was also a series of stakeholder consultations on scenario building during the case study areas analyses.

A stakeholder panel is a tool that enables stakeholder integration in a project. It provides a platform for active consultation process, where stakeholders can express their problems and concerns about the given issue, provide feedback on the project results, help in developing scenarios and adaptation measures, and assist in networking with other stakeholders whenever needed. It is also a process where the experiential knowledge of stakeholders can be incorporated with the scientific knowledge.

The identification of a Stakeholder Panel (SP) normally follows through several stages. In the process, the technical, political, and ethical rationality needs to be considered. The process has to address some important questions about legitimacy, representation, and credibility. This can be undertaken by stakeholder mapping. Stakeholders will be included based on how much they can influence the process. Clearly, the choices of whom to include, how, when, and why, are dependent on their effectiveness and value in the process (their interest and influence).

A larger stakeholder workshop, could set the stage for a SP selection. The project team, with the help of some key stakeholders may come up with a probable panel as a starting point for SP selection. The list then needs to be circulated and discussed with key stakeholders, and based on their feedback it should be revised. After revision the members have to be approached for their consent to participate in the project panel. Whether a SP is possible has to be clear before actually involving the stakeholders. This must be discussed with some key stakeholders and also determine what the level of participation can be expected. Also a preliminary set of ground rules for the process have to be designed. Often this is a challenge in research projects, due to resource constraints. It is also difficult to motivate the stakeholders unless they see a direct benefit in the process for themselves.

Check the following:

1. To check if the list includes relevant stakeholders interested in the issue.
2. To ensure that due representation is given based on their role (Managers, Farmers organizations, NGOs, Extension agencies from local and regional level etc.)
3. To rate, if possible, the stakeholders on a 1-4 scale based on their influence and interest (1 –Most influential and most interested and 4 –least influential and least interested), and select SP based on that.

Terms and conditions for SP members:

- To participate in meetings as agreed during the Aquaclimate project period (at least take part in two panel meetings in a year)
- To contribute positively and actively to the development of scenarios and adaptation measures or strategies in the Aquaclimate project
- To further take the results and communicate with policy makers
- To keep confidentiality and not to disseminate or use the results from the project without prior permission of the project co-ordinator.
- To assist in strengthening the networks between the project partners and other stakeholders

Specific terms to small scale aquaculture

We would need stakeholders that represent:

- the small-scale pond producers (owner operators)
- government and institutional support to the producers
- Upstream industries such as hatcheries and fry collectors
- Downstream industries such as deboning and processing

2. Data collection

2.1 Focus group meetings

For the socio-economic vulnerability assessment, focus groups together with stakeholder workshops and individual farmers' surveys will be used to gather data necessary for the analysis. The size and selection of the focus groups is important, and the purpose of the study will guide the selection of the focus group members. The normal recommended size of a focus group is 8-10. The farmers' selected (through stratified random sampling) will represent fish famers in different locations of the study area, from different age groups (with varied experience in farming) and owning farms of different sizes.

Focus group objectives

1. To map farmers perceptions about climate change and likely impacts on small scale aquaculture systems in particular
2. To assess vulnerability of the production system to climatic changes and extreme climatic events
3. To estimate the economic losses for the farmers due to extreme climate events
4. To map the adaptation measures that farmers/communities respond with, when exposed to extreme climate events
5. Map the agencies involved with aquaculture planning and management and what involvement they have with Climate change

Focus group process

A. Farmers' Perception and Climate Change
   1. Identify the 3 main risks of extreme events/climate change and rank them according to importance, i.e. 1 being the most important and 3 the least (1 meta card – pink)
   2. Leader from each group comes to the front and explains why the climate change even is important. Continue until all the cards are on the board
   3. Facilitator together with the participants will group the ideas (same or similar ideas in one column)

B. Production Impacts.
   Identify the impacts (purple card) to production for each of the grouped extreme event/climate change event starting with the one that has been identified with the most cards.

C. Climate Change Economic Impacts
   Identify the cost of each impact, e.g. cost of repair, cost of loss of fish harvest, etc (1 meta card- yellow).

D. Climate Change Responsibility
   Identify the responsible agency/person that can help with the each impact (1 meta card-blue)

E. Risk Assessment and Analysis
   1. Using the risk analysis codes, classify each impact/extreme event, i.e. likelihood rating, risk consequence scales, risk level (1 meta card-orange).
   2. Plot on the matrix and get the average and range.

F. Seasonal and Crop Calendar

The focus groups can generate a lot of relevant information during the discussions. To begin with, adequate background information was provided to the focus groups about the project, purpose of the meeting and expectations from the meeting. The participants were given freedom to express themselves, disclose their practices and ideas, both positive and negative. Least interference by scientific personnel is recommended to allow free expression of opinion.

The group responses are taken as collective opinion. Preferably the focus group meetings should take place close to the farmer's farms in a comfortable setting where farmers can express their opinions freely.

Farmers were divided into groups of 3-4. Each group of three had to discuss among themselves and present their findings to the others at each step of the process.
Step 1. Identify the agencies extreme events suffered by the farmers
Step 2. Identify the impacts of those extreme events
Step 3. Action taken by the farmer to deal with or rectify the problem
Step 4. Estimate of costs to deal with or rectify the problem
Step 5. Which agency could help the farmers in future extreme events

SEASONAL AND CROP CALENDARS

Objectives

- To identify periods of stress, hazards, diseases, hunger, debt, vulnerability, etc.
- To understand livelihoods and coping strategies
- To analyze changes in seasonal activities
- To evaluate use of climate information for planning

This activity should take approximately 2 hours including discussion: 30 minutes for each of the calendars, and 45 minutes for the discussion.

1. Use the ground or large sheets of paper. Mark off the months of the year on the horizontal axis.
2. Explain to the participants that you would like to develop a calendar to show key events and activities that occur during the year.
3. Ask people to list seasons, events, conditions, etc., and arrange these along the vertical axis. The list should include:
   a. Holidays and festivals
   b. Planting and harvest seasons
   c. Seasonal climate
   d. Timing of hazards/disasters such as cyclones, droughts and floods
   e. Timing of farming practice
   f. When common seasonal illnesses occur
   g. Etc.
4. When the key events have been listed, plot the timing of them in the table based on agreement among the participants.

Seasonal calendar	J	F	M	A	M	J	J	A	S	O	N	D
Dry season												
Risk of droughts												
Risk of saline intrusion												
Rainy season												
Risk of floods												
Hot spells												
Storm weather												
Holidays												
Etc.												

Crop Calendar												

Pond preparation												
Pond stocking												
Grow out												
harvesting												
Etc.												
Risks												
Disease risks												
Water quality risks												
Mortality risks												
Etc.												

Learning and Discussion

When the calendar is complete, ask the group members the following questions:

- What are the most important fish production strategies employed at different points of the year?
- What are current strategies to cope during the difficult times? Are they working?
- Have fish production strategies changed based on the changing seasons or events?
- How are decisions made on timing of fish production strategies?

2.2 Risk Assessment Methodology

Risk Assessment terminology is given below:

- **Risk** – The chance of something happening that will have an impact upon successful commercial production. It is measured in terms of consequence and likelihood;
- **Consequence** – The outcome or impact of an event expressed qualitatively or quantitatively, ranging from 5. Catastrophic to 1. insignificant or positive;
- **Likelihood** – Used as a general description of probability or frequency. Can be expressed qualitatively or quantitatively from 5. Almost certain to 1. Rare;
- **Risk Management** – The culture, process and structures that are directed towards effective management of potential opportunities and adverse effects.

Risk Likelihood Ratings

Rating	Recurrent Risks	Single Events
Almost Certain	Could occur several times per year	More likely than not - Probability greater than 50%
Likely	May arise about once per year	As likely as not - 50/50 chance
Possible	May arise once in ten years	Less likely than not but still appreciable - Probability less than 50% but still quite high
Unlikely	May arise once in 10 years to 25 years	Unlikely but not negligible - Probability low but noticeably greater than zero
Rare	Unlikely to occur during the next 25 years	Negligible - Probability very small, close to zero

Risk Consequence Scales

Rating	Economic	Social and Community	Environment & Sustainability
Catastrophic	Business failure	Loss of employment, livelihood and hardship	Major widespread environmental impact and irrecoverable environmental damage
Major	Business are unable to thrive	Reduced quality of life	Severe environmental impact and danger of continuing environmental damage
Moderate	Significant general reduction in economic performance relative to others	General appreciable decline in services	Isolated but significant instances of environmental damage that might be reversed with intensive efforts
Minor	Individually significant but isolated areas of reduction in economic performance relative to others	Isolated noticeable examples of decline in Quality of life	Minor instances of environmental impact that could be reversed
Insignificant or positive	Minor shortfall in profitability relative to others or positive	There would be minor areas in which the region was unable to maintain its current services	No environmental impact or benefits to the environment

Risk Priority Matrix

Consequence Likelihood	1. Insignificant	2. Minor	3. Moderate	4. Major	5. Catastrophic
5. Almost Certain	5 = Medium	10 = Medium	15 = High	20 = Extreme	25 = Extreme
4. Likely	4 = Low	8 = Medium	12 = High	16 = High	20 = Extreme
3. Possible	3 = Low	6 = Medium	9 = Medium	12 = High	15 = High
2. Unlikely	2 = Low	4 = Low	6 = Medium	8 = Medium	10 = Medium
1. Rare	1 = Low	2 = Low	3 = Low	4 = Low	5 = Medium

Risk Level Descriptors	
Extreme	Risks demand urgent attention and adaptation solutions need to be found as soon as possible at all levels.
High	Risks are the most severe that can be accepted as part of routine operations but adaptation solutions need to addressed quickly.
Medium	Risks can be expected to form part of routine operations but adaptation solutions need to be developed in the medium term and the risk monitored regularly.

Low	Risks will be maintained under review but it is expected that existing farm management will be sufficient and no further action will be required to find adaptation solutions unless they become more severe.

2.3 Stakeholder workshop

The workshops helped to achieve the following outcomes:

1. Introducing AquaClimate project to the stakeholders
2. Exchange of perspectives between different stakeholders about climate change and impacts on aquaculture
3. Promoting awareness within the stakeholders about the on-going climate change related projects in the region and possible synergies
4. Exploring possibilities for co-operation with stakeholders in the AquaClimate project
5. Establishing a stakeholder panel that acted as the reference group for AquaClimate project for close interaction and developing scenarios

The morning session was dedicated to

- **Workshop opening and introductions**. To welcome people and enable participants and facilitators to get to know each other.
- **Objectives and schedule**. To outline the objectives, content, methods and timings of the workshop.
- **Presentations**. To give information about the project, climate change and potential impacts.

The afternoon session was totally devoted to “Facilitated Group Work” involving fish farmers, scientists, commercial companies and Government officials from related fields. The stakeholders were divided into three groups, each group consisting of 12-14 stakeholders, based on their occupation, in order to map the differences in perceptions related to climate change. The different groups were:

- Group I - Comprised mostly of fish farmers and from commercial companies.
- Group II – Representatives from Academia, research and scientific staff
- Group III - Managers from various government agencies

Each group was assisted by a facilitator and a translator to guide the discussions. During the discussions, the group members were made to sit into sub groups of 3-4 stakeholders each. This was to facilitate active participation of all stakeholders in the discussions.

Process:

Step 1. Scenario setting and CC Issue identification: Identify/define climate change (based on personal experience or observation)
Step 2. Prioritisation of issues, and rank the CC identified
Step 3. Identify the impacts
Step 4. Identify mitigating measures (existing or ways on how to address)
Step 5.. Identify the responsible agency that can implement the mitigating measures

Each sub-group was given different colour cards to write down the most important major climate events, impacts and adaptation measures. The events were grouped and then ranked by stakeholders in the order of their seriousness. The stakeholders in the next stage listed the possible impacts of each event on cat fish farming based on their experience. The impacts were also then ranked based on the importance as perceived by stakeholders. This was followed by suggesting suitable adaptation measures, for each impact and agencies that should be responsible for implementing the measures.

Workshop recaps. To provide a summary (usually by participants at the end of the identification and prioritisation) to inform the other groups.

3. Data Analysis

3.1 Stakeholder mapping and analysis

A stakeholder is any person or organization, who can be positively or negatively impacted by, or cause an impact on the actions of a company. Types of stakeholders are:

- **Primary stakeholders** : are those ultimately affected, either positively or negatively by corporation's actions.
- **Secondary stakeholders :** are the 'intermediaries', that is, persons or organizations who are indirectly affected by corporation's actions.
- **Key stakeholders :** (who can also belong to the first two groups) have significant influence or importance in corporation.

A stakeholder analysis is performed when there is a need to clarify the consequences of envisaged changes or at the start of new projects and in connection with organizational changes generally. It is important to identify all stakeholders for the purpose of identifying their success criteria and turning these into quality goals.

Undertake stakeholder mapping

The first step in building any stakeholder map is to develop a categorised list of the members of the stakeholder community. Once the list is reasonably complete it is then possible to assign priorities in some way, and then to translate the 'highest priority' stakeholders into a table or a picture. Interaction with the potential list of stakeholders for any project will always exceed both the time available for analysis and the capability of the mapping tool to sensibly display the results. The challenge is to focus on the 'key stakeholders' who are currently important and to use the tool to visualise this critical sub-set of the total community.

The most common presentation styles use a matrix to represent two dimensions of interest with frequently a third dimension shown by the colour or size of the symbol representing the individual stakeholders.

Some of the commonly used 'dimensions' include:

- Power (high, medium, low)
- Support (positive, neutral, negative)
- Influence (high or low)

3.2 Institutional Mapping and analysis

Institutions play a critical role in supporting or constraining people's capacity to adapt to climate change. In order to better understand which institutions are most important to people in the target communities, an institutional mapping exercise is useful.

Key issues in the analysis included:

- Which organizations (governmental and non-governmental) are involved in addressing key aquaculture issues and problems related to climate change?
- What are the policy or strategy documents that guide their work?
- What are their activities that are relevant to adaptation?

- Do they have a mandate to address climate change issues?
- What is the institution's level of influence in addressing adaptation?
- What are their relationships with other organizations?
- What are the strengths and weaknesses of the institutions?

The institutional analysis provided useful information to plan the scope of the policy analysis, and to identify key stakeholders for further investigation. The mapping exercise assisted in identifying the institutions that should be engaged in the process, as well as potential allies and opponents in addressing vulnerability at the community level.

For the most important Institutions, a deeper examination was domeusing some of the following questions:

- Which are the key organizations (governmental, non-governmental and community-based) that are involved in addressing key issues and problems related to climate change?
- What do they do?
- Where do they work?
- How do they interact with the target population?
- Where are the overlaps with other organizations?
- Where are the gaps in capacity?
- How might some organizations impede the work of others?
- What are their longer term plans for working in the area?
- What are the strengths and weaknesses of the institutions?
- What is the institution's level of influence over planning and implementation of adaptation?

3.3 Policy Analysis

Decisions made by governments can have a profound effect on the ability of communities to adapt to climate change. Policies in sectors such as water, agriculture, health, infrastructure, and economic development can facilitate or constrain adaptation. Integration of climate change considerations into these policies can ensure that they contribute to adaptive capacity from national to local levels. In some cases, existing policies provide opportunities to address climate change – as long as the capacities, resources and political will are in place to ensure they are implemented.

It is important to understand these dynamics and how they may affect adaptive capacity at the local government/ community, and household/individual levels. Therefore, the CVCA process should analyze relevant policies, focusing on the integration of climate change issues into policies, and on openings and barriers to facilitating adaptation in target communities.

Depending on the degree of decentralization of decision-making in a particular country, local-level plans or policies may be important in shaping adaptive capacity of vulnerable households and individuals. Regional or district plans and/or sector strategies can give helpful information on priorities of local governments. Further, the process for developing these policies and strategies can provide insights into the level of participation of vulnerable people in establishing these priorities. The status of implementation can yield useful information on resource and capacity constraints faced by local actors.

Institutional Context Related to Climate Change

- Describe government structures to address climate change.
- Describe and assess capacity of relevant institutions to integrate climate change considerations into their work.
- Provide analysis of linkages between national policies and local implementation.
- Provide analysis of resource allocation for adaptation-related activities at national and local levels.

Underlying Causes of Vulnerability

- Provide analysis of impact of policies and programs on access to and control over critical livelihoods resources.
- Provide analysis of impacts of policies and programs on women and other marginalized groups.
- Describe and evaluate participation (particularly of vulnerable groups) in policy decisions at national and local levels.
- Provide analysis of inequalities within communities or households which exacerbate vulnerability (such as access to services, control over resources, mobility, etc.).

3.4 Key Stakeholder Interviews

Key stakeholders can provide useful insights into local governance structures and status of implementation of local policies and programs. Power issues within and between communities and other stakeholders can also be surfaced through interviews with key actors. Again preserving their anonymity may allow them to speak more freely.

Key informants at the local government/community level would include:

- Local leaders (chiefs, mayors, elected representatives, etc.)
- Representatives of community-based organizations (CBOs) such as farmer's groups, savings and credit groups, etc.
- Representatives of women's groups or other rights-based groups
- Representatives of NGOs working on programs or advocacy in the target area
- Academic/research institutions engaged in the target area

3.5 Generic GIS Analysis Methodology for future predicted climate change

Climatic factors, such as air and water temperature, and precipitation and wind patterns, strongly influence fish health, productivity and distribution. An analysis was made of the 16 models used in the Asia Pacific region and the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) – A1, A2, B1 and B2 to be used as the basis for predicting future climate for this study. In addition a decision was made on the commonly considered time periods – 2020s (2010-2039), 2050s (2040-2069) to be used. Another factor that was considered in choosing the model was the availability of the data and that the output can be effectively used in combination with GIS. GIS facilitates the analysis of multiple layers of data and allows statistical analysis of multiple factors while maintaining their spatial representation.

The analysis recommended the use of the CSIRO climate model available from WORLDCLIM and the A2 scenario "business as usual".

The A2 scenario can be summarised as follows;

- a very heterogeneous world.
- self-reliance and preservation of local identities.
- Fertility patterns across regions converge very slowly, which results in continuously increasing population.
- Economic development is primarily regionally oriented
- per capita economic growth and technological change more fragmented and slower than other storylines.

The output from this climate model and scenario was used to predicted future Climate Change for the 4 case study areas for the timescales Present, 2020 and 2050.

Climate changes that were considered included;

- Temperature increase and seasonal patterns
  - minimum average monthly temperature
  - maximum average monthly temperature
- Precipitation change and patterns for the
  - Municipalities indicating precipitation at the farm ponds
  - River water shed area indicating potential change in river flows
- Sea Level Rise
- Storms and cyclones
- Storm surge risk

3.6 Global warming potential and resource use analysis

This study uses the techniques of LCA to look at global warming potential and resource use from small scale aquaculture in Asia and benchmark this against other Aquaculture sectors.

LCA methods are initially developed for land-based industrial applications, and the methodology is so far not brought to the same level when it comes to food products, especially not for fish.

Several studies related to fish products, however, are available. Among these are Ziegler (2001), Ziegler et al. (2003), Thrane (2004), Christensen and Ritter (2000), Eyjolfsdóttir et al. (2003), Silvenius and Grönroos (2003) and Mattsson et al. (2003). It is generally agreed that better adapted environmental indicators are needed for both wild caught and farmed fish.

In practice, impact assessment components of LCAs concentrate on global impact categories (climate change and ozone depletion) and on regional impact categories (e.g. acidification, tropospheric ozone formation, and eutrophication).

Life cycle assessment (LCA) is the modelling of the interaction between the production of a product and the environment. LCAs compile the emissions (air, water, soil, waste etc.) and resource uses of a product much the same as a bookkeeper tallies up figures. The data usually describe the path of a product from "cradle to grave." This includes sourcing of raw materials, production of materials and the main product, and finally the usage of the product and disposal.

LCAs are developed in order to compare a product with respect to corresponding environmental and climate impacts. In order to accomplish this, the entire life cycle of the product must be identified and all relevant forms of known environmental interventions should be accounted (Nath et al. 1998). Analytic tools that are related to LCA include: life-cycle assessment, design for environment, life-cycle cost accounting, eco-efficiency, environmental auditing or profiling, environmental benchmarking, and environmental performance evaluation (Lowe 1997).

Global Warming Potential = The potential impacts on global warming associated with the inputs and outputs of the life cycle of product (i.e. the system boundary of LCA study).

The principle of GWP calculation is to multiply the amount of GHG emissions with the characterisation factor of each GHG (called as "Characterisation factor" in LCA), for instance, CO_2 has the GWP = 1 kg CO_2 while CH_4 has the GWP = 25 kgCO_2e (meaning that CH_4 has the higher impacts than CO_2 about 25 times).

Thus, if the whole life cycle of product emits 1 kg of CO_2 and 1 kg of CH_4 therefore the total GWP value = (1X1) + (25X1) = 26 kgCO_2e

The unit is kgCO_2e meaning kg CO_2 equivalent, as equivalent to 26 kg of CO_2 so it is the relative impacts not actual value.

Wild fisheries resource Use

For the purpose of this report, the IFFO formula was adopted and used to analyse the use of fish meal and fish oil for the production to determine the Fish in: Fish out ratio.

IFFO methodology (Jackson, 2009)

The IFFO method applies the following equation:

$$\text{IFFO FIFO Ratio} = \frac{\text{Level of fishmeal in the diet + level of fish oil in the diet}}{\text{Yield of fishmeal from wild fish + level of fish oil from wild fish}} \times \text{FCR}$$

This model corrects the Tacon and Metian (2009) model that implies that the extra fishmeal is wasted and takes into account of both the fishmeal and fish oil use. However, the model is biased against fish with high lipid levels such as salmon, trout and eels due to the differential between some species of cultured fish with high lipid level compared to wild fish used for the production of fish meal and fish oil.

Additional impacts from use of biotic resources as fish resources (fish meal and fish oil), water use, land use and the sea/lake surface use were also analysed.

3.7 Economic Analysis Methodology

The Applied Aquaculture Production Function (AAPF) estimation along with Major Operating Cost Structure (MOCS) has been investigated for these major aquaculture parameters in all aqua-farm activities. The AAPF is basically drawn from production function estimation through its monetary value by an application of duality theory. Initially, a general production function can be presented as;

$$\text{Output} = f(\text{Input}_j) \tag{1}$$

The output (O) generally represents the obtained amount of production from all inputs "j" utilized within the production period. These inputs can be further categorized into 3 main groups; Physical Aspects of the Production System (PA), Production Management Aspects (PMA) and Production Input Aspects (PIA) (See Table 1), respectively.

A modified production structure through an assistance of cost structure based on the duality theory can be demonstrated as:

$$O_i*PO_i = f(PA_{ij}, PMA_{ij}, PIA_{ij}* P_{ij}) \tag{2}$$

For converting PIA into monetary unit for each "i" (i = individual farm) and "j" (j = type of input), the PIA can be multiplied with the price per unit (P_{ij}). The Output (O_i) can also be measured in monetary unit[3] by multiplying a price of output (PO_i).

In order to capture an impact of climate change as an external factor unavoidably incorporated into the production system, the Climate Change Impact(s) (CCI) by "i" type can be added into the AAPF model as:

$$O_i*PO_i = f(PA_{ij}, PMA_{ij}, PIA_{ij} * P_{ij}, CCI_{ij}) \tag{3}$$

The general form of AAPF (3) is given by the following equation (4):

$$O_i * PO_i = b_0 + \sum_i b_{ij}^{PA} PA_{ij} + \sum_i b_{ij}^{PMA} PMA_{ij} + \sum_i b_{ij}^{PIA} PIA_{ij} P_{ij} + \sum_i b_{ij}^{CCI} CCI_{ij} \tag{4}$$

In addition to statistically selected inputs in AAPF estimation, an adjusted-R^2 or coefficient of determination commonly provides a goodness of fit test. In other words, based on AAPF setting, it can measure how well each individual's revenue explained by each individual's direct and indirect investment.

According to technical efficiency, the coefficients obtained from (4) can be performed an elasticity calculation to compare a relative importance (ranking) of independent variables as follows:

$$E_{O/PA_{ij}} = b_{ij}^{PA} \frac{PA_{ij}}{O_i * PO_i} \tag{5}$$

$$E_{O/PMA_{ij}} = b_{ij}^{PMA} \frac{PMA_{ij}}{O_i * PO_i} \tag{6}$$

$$E_{O/CCI_{ij}} = b_{ij}^{CCI} \frac{CCI_{ij}}{O_i * PO_i} \tag{7}$$

The elasticity can be computed at the means of variables (i.e. Mean values of PA, PMA, CCI and O*PO). The result obtained from AAPF and its technical elasticity can be used as a guideline for obtaining Economic Vulnerability Indicators (EVI).

Meanwhile, the Major Operating Cost Structure (MOCS) can also provide some basic information to support the AAPF result since the each "j" Major Operating Cost (MOC) from

[3] Perfectly competitive market and rational maximizer assumptions have been applied.

MOCS can explain a way of each individual's input investment for obtaining their targeted outputs. MOC can be simply calculated by:

$$MOC_j = \frac{MOC_j}{\sum_j MOC_j} \tag{8}$$

And MOCS can provide a general ranking based on each individual investment for their major input during their aqua-farm activities. In addition to MOCS calculation, a common Feed Conversion Ratio (FCR) can be further transformed to 'modified FCR (mFCR)' as:

$$FCR = \frac{Total\ Feed\ Mass(kg)}{Total\ Body\ Mass(kg)} \Rightarrow mFCR = \frac{Total\ Feed\ Mass(kg) * Feed\ Cost(value/kg)}{Total\ Body\ Mass(kg) * Fish\ \mathrm{Pr}\,ice(value/kg)} \tag{9}$$

The mFCR is capable of measuring the feed conversion efficiency for both intensive and extensive culture systems through a common ground on a ratio of revenue obtained from feed cost used (direct or indirect feed cost). The optimal range for commercial catfish production FCR, which is equal to 1.2 – 1.5, can be used as a reference for both actual FCR and mFCR comparisons.

3.8 Future Climate Change Scenarios

The challenge now is to develop methodologies to include stakeholders and the public in policy making. According to Gooch and Huitema (2007) a number of methods are available to enable stakeholders to participate in environmental management, including, citizen juries, stakeholder panels etc. However these methods may not be able to include all sections of the society who are affected by climate change. One way of engaging stakeholders and the farmers in the formulation of possible futures is through the use of scenarios. Scenarios are projections of possible futures (Alcamo 2001; Shell 2003), not necessarily the most likely futures.

In AquaClimate (www.enaca.org/aquaclimate), a major focus was on the involvement of stakeholders and the public in the development of scenarios and adaptation models for sustainable aquaculture in the respective case study areas. Scenarios provide a means to map possible future situation and the measures necessary for sustaining aquaculture production. Scenarios can also be used as a tool for improving stakeholder participation. Involvement of stakeholders in the development and validation of scenarios can provide insights not readily available for policy-makers.

Scenario as a policy tool

Scenarios essentially describe possible future situations and the path that may make it possible to arrive at such a future situation.[4] They are a useful tool to look at possible paths of development, to illustrate how alternative policy pathways can raise awareness about the future environmental problems, pinpoint priority issues, identify the main actors in relation to the key variables and their strategies, and provide education and operational strategies.2 Scenarios are verbal picture of a situation or a phenomenon based on certain assumptions and factors (variables). Scenarios are used in estimating the probable effects of one or more variables, and are an integral part of situation analysis and long-range planning.

[4] 'Scenarios' has been defined as "a sequence of emerging events, an account of a projected course of action or events" (Webster's Ninth Collegiate Dictionary, 1989); the IPPC define "scenarios" as "images of the future, or alternative futures that are neither predictions nor forecasts, but an alternative image of how the future might unfold" (Alcamo, J., "Scenarios as tools for international environmental assessments", Experts' corner report, Prospects and Scenarios No. 5, European Environment Agency, Copenhagen 2001, at 7).

Scenarios can be made up of

1. a base year -usually the current year, which provides a starting point for assessing scenarios;
2. time horizon -the most distant future year or end year covered by a scenario;
3. pathways -description of the changes that may take place from the base year to the end year;
4. drivers – the main factors or determinants that influence the pathways described in a scenario; and
5. storyline – a narrative description of a scenario which highlights its main features and their relationship to the driving forces.

Advantages of developing scenarios together with stakeholders

1. The experiential knowledge of stakeholders together with the scientific knowledge will be useful to develop most realistic scenarios.
2. Scenarios are useful tools to integrate knowledge from various disciplines and sectors.
3. Stakeholder inputs would be useful to develop more meaningful adaptation strategies, as they would be aware of the resources and limitations and the immediate needs.
4. The scenarios thus developed would be of direct use to managers and decision makers and easy to implement.
5. Scenarios developed through active participation can increase awareness of the issue amongst stakeholders and at the same time build trust between the scientific and civil society.

Constraints in the development and use of scenarios

1. Stakeholder involvement can be time consuming, as it requires several meetings, workshops, and interactive sessions, before trust is developed.
2. Identification of relevant stakeholders is one of the key constraint and often a cumbersome process. Selection can be biased and in the process potential stakeholders can be left out
3. In some situations it is difficult to communicate with local agencies and farmers due to language barriers.
4. Stakeholders might build some expectations when asked to participate and projects like AquaClimate may not be able to meet the expectations. It is better to inform about the purpose of their involvement and the project limitations.

4. Recommendations

4.1 Policy briefs

Policy makers seldom have the time to read through all the literature related to a specific policy question. To make well-informed decisions, they rely on short, tightly written briefs that quickly and cogently relay the important policy facts, questions, and arguments about an issue. The policy brief should advance a persuasive argument in a concise, clearly organized fashion. A policy brief does not include a lengthy analysis or review of the literature. The Policy brief should conclude with policy recommendations.

4.2 Science and Technology Briefs

Scientific research and technology development can play a strong role to support farmers in developing new adaptation measures to predicted future climate change as well as developing standardised methodology for assessing socio-economic vulnerability of communities and culture systems and developing adaptation measures.

There is a need for scientific research to understand the underlying biological processes that are affecting productivity changes due to climate change and develop potential solutions for the farmer. This includes research on subjects such as the effect of temperature on breeding and fry fitness and the selective breeding of temperature tolerant stains, research on the effect on pond primary productivity and the biological control of snails in the ponds. In addition, there is a need for scientific research to better understand climate change and its potential impacts to support informed decision making by central, regional and local governments.

The development of technology can also pay an important role such as engineering stronger dikes, development of breakwaters that encourage natural mangrove development to protect coastlines vulnerable to sea level rise and storm surge.

The new adaptation technologies will need to be cost effective, environmentally sustainable, culturally compatible and socially acceptable. The technologies will also need to be implemented which will require widespread technology transfer supported by effective institutions, formal and informal. Funding will need to be identified to pay for the necessary research and technology development.

Even if new technologies are devised, and are suitable for local conditions, it can be difficult for the poorer farmers to adopt them. With small farm sizes and limited access to credit, they may have neither the ability nor the inclination to invest in new technology.

Whatever the envisaged levels of technology, it is clear that there is a need to devise national strategy for adaptation, assessing the communities and the locations at greatest risk and planning appropriately. The scientific predictions and warnings may not yet provide the level of precision desired by many planners, but they portray with certainty a rapidly warming world with consequences that globally, and for most sectors, are largely negative. A new climate is on the way. Adaptation is not a choice, it is a necessity

Many of these technologies are already available and widely used. The global climate system has always confronted human societies with extreme weather events and in many respects future climate change will simply exacerbate these events, altering their scale, duration or intensity. Thus it should be possible to adapt to some extent by modifying or extending existing technologies.

4.3 Farmer technical briefs

The farmer can adapt to small changes in weather patterns and short term gradual climate change but they are not prepared for rapid changes or long term continuous climate change. The farmer needs to be assisted by scientific research and technology development to find solutions that will allow them to adapt to the predicted future climate changes.

The farmer can implement a wide range of adaptation measures on the farm ranging from purchase and use of technology, changes in pond design to changes in production methodology and timing.
However, small scale farmers do not have the financial resources to undertake many of the potential adaptation measures and with present market prices, they are barely breaking even.

Therefore it is important to assist the farmers now to become more profitable so that they can cope with the stronger and more unpredictable weather conditions and afford make the recommended adaption measures.

The farmer needs to make a decision to resist climate change or to accept climate change and find ways to live with the consequences. For example, increased peak rainfall together with increasing sea level rise is leading to increased frequency and higher floods. To resist this impact the farmer can resist flooding by strengthening and increasing the height of the perimeter dikes. To live with flooding, the farmer can purchase nets that are deployed on the top of the dykes so that when a flood occurs, the fish remain in the ponds.

4.4 Policy options and trade-offs

One of the objectives of the AquaClimate Project is "to develop guidelines for policy measures and decision support tools", which will contribute to an increase in resilience and enhance adaptive capacities of resource-poor, small-scale aquaculture farmers and those dependent on aquatic resource for their livelihoods, to the impacts of climatic change. As aquaculture has multiple sets of stakeholders that have direct and varying interests in (as well as influence on) the sector, and who might benefit or be harmed by an action or policy, it will be important to determine the attitudes and preferences of various interest groups towards the identified/proposed actions and policies. The prioritization of policy options based on stakeholder's perceptions will help in guiding the policy makers to reformulate their strategies to cope with the expected climate change conditions.

The project identified three main groups of stakeholders, which are 1) farmer group, 2) science and technology group, and 3) policy and institution group. The weighting of policy options of each group was determined by using Analytical Hierarchy Process (AHP) (Saaty, 1977) as a tool and then the hierarchy (ranking) of decision elements was developed (Saaty, 1990). AHP provides the decision makers with a comprehensive framework for solving problems particularly when they make multi-criteria and multi-actors decisions. The perceptions and purposes can be integrated into an overall synthesis by using AHP (Saaty, 1990).

A trade-off analysis (also called a trade study) is an analytical method or tool for evaluating and comparing system designs based on stakeholder-defined criteria. The stakeholders were asked to investigate alternatives (issues/measures) and to compare and select the best alternative to answer a basis question, which is "Are the solutions that are being suggested as good as possible?". The alternatives (issues/measure) were investigated based on the overall feasibilities, which are:

- Economic feasibility = "Cost-Benefit analysis" of related parties
- Technical feasibility = Ability for new development and new technique evaluation by related parties
- Operational feasibility = Usability (performance, efficiency etc.)

The AHP and trade-off analysis were integrated and used as tools in this project for developing the policy options and framework. For weighting the climate change issues, the stakeholders considered whether the issues were urgent in term of calling for immediate measures or not and while weighting the measures for the respective climate change issues, the stakeholders used "trade-off analysis" as criteria for decision making.

A very important practical application for government would be balancing the allocation of resources for specific purposes and to specific sectors for the purpose of increasing their overall adaptive capacities to manage a broader set of risks (rather than to specific risks) to their livelihoods and security.

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Annex 2: Briefs

Policy brief: Policy and Institutions

Vietnam recognized the threat posed by human-induced climate change by ratifying the UNFCCC in 1994 and the Kyoto Protocol in 2002. The Initial National Communication (INC) to the UNFCCC (MONRE 2003) only explored climate change impacts and necessary adaptation measures in a preliminary and qualitative way. More in depth analysis of each sector has been taken up, but all sectors have not been covered adequately.

Vietnam, particularly the Mekong Delta is potentially one of the world's most vulnerable countries to climate change due to its geographical location and low lying and deltaic coastline. Therefore, Vietnam considers response to climate change is vital and climate change adaptation and GHG reductions will be implemented simultaneously, adaptation is the priority in the early phase of the strategy implementation. Recently, key institutional and policy support for adaptation in both aquaculture other related sectors:

- National Target Program to Respond to Climate Change (NTP-RCC) was released in December 2008.
- "Climate Change, Sea Level Rise Scenarios for Vietnam" document was released by the Ministry of Natural Resources and Environment (MONRE) in June 2009.
- Action Plans to Respond to Climate Change (APRCC) was released on the 20th December 2010 by the Ministry of Natural Resources and Environment (MONRE).
- Action Plans to Respond to Climate Change (APRCC) was released on the 23th March 2011 by the Ministry of Agricultural and Rural Development (MARD).
- National Climate Change Strategy (NCCS) was approved on the 5th December 2011 by Prime Minister (No 2139/QD-TTg).
- National Action Plan on Climate Change is preparing and will submit to the Prime Minister sometime in 2012 for approval.

The Ministry of Natural Resources and Environment (MONRE) is assigned to coordinate all activities related to climate change in Viet Nam. In all provinces and line ministries there is one focal point for climate change activities. The main tasks of this office are to prepare action plans and coordinate for the implementation of climate change activities in their Provinces/Ministries.

At the national level, the Ministry of Natural Resources and Environment (MONRE) is the national focal agency for climate change related activities. Climate change adaptation measures have been included in a number of recent laws and strategies, such as the National Strategy for Environmental Protection (2005), which includes measures for reducing the impact from sea level rise in coastal zones. In early 2006, the MONRE-based International Support Group on Natural Resources and Environment (ISGE) established a climate change adaptation working group, which provided a forum for dialogue and should promote coordination for climate change adaptation measures.

The Government of Vietnam adopted its National Target Program to Respond to Climate Change (NTPRCC) in 2008, thus setting goals that involve a range of inter-sectoral institutional measures and reflect the cross-cutting nature of the impacts of climate change. These include vulnerability assessments across sectoral, regional, and community levels; enhancing the role of science and technology for adaptation solutions; increasing public awareness and participation; and integrating climate change into development strategies, plans, and programs in all sectors.

The Ministry of Natural Resources and Environment (MONRE) has approved Action Plan to response to climate change for the period 2011-2015.

The Ministry of Agriculture and Rural Development (MARD) has promulgated Action Plan Framework on adaptation to climate change for the Agriculture and Rural Development Sector, period 2008 – 2020, which also covers Aquaculture sector.

The policy options and adaptation measures for Aquaculture sector need to be prepared. These have to also meet the needs of the Environment, Land use and Water sector climate change policies.

The Department of Agriculture and Rural Development (DARD) can play an important role in the implementation of the adaptation measures. The DARD could provide information and training to the farmer on the potential climate changes and their impacts.

Climate change perceived by local farmers is: (1) High temperature and irregular weather, (2) Irregular and too much rain, (3) Sea level rise, (4) storm surges. High temperature and irregular weather according to farmers cause massive losses for shrimp farming, followed by too much rain, sea level rise and storm surges. The results from the farmers also confirm that irregular weather and high temperatures are significant concerns for shrimp farming in the Mekong Delta. Those serious climate change events need to be taken up and also the agencies that would be most relevant or appropriate for implementing the measures. These measures include:

- ❖ Exchange of information and training of trainers and extension workers on climate change: climate change and sea level rise scenarios of Vietnam, especially in the Mekong Delta should regularly update for decision/policy makers and trainers. Action Plan to response to climate change of both MARD and MONRE also need to update for trainers. This is considered as a long term. Climate change awareness workshops for Vietnamese agencies such as DARD that will help in better policy development.
- ❖ Plan and zone for aquaculture at sustainable development: GIS tools and analysis should be considered to plan for sustainable levels of aquaculture development: Examine the land use and identify the most vulnerable area or suitable for aquaculture development, area for

each farming model. In addition, stakeholder meetings for discussion and agreement should be conducted before implementation. DARD can cooperate with Institutes/Universities to assist this mater.

- ❖ Improve existing irrigation systems and construct coastal dykes: It is predicted that sea level could increase at least 30cm by 2050 in the Mekong Delta and 75cm by 2100. The Government should allocate a reasonable budget to construct and protect coastal lines. Vietnam Government has been considering to construct concrete dykes long the coastal lines of the Mekong Delta against to climate change impacts, sea level rise in particular. There is a need for research fund and investment in infrastructure such as dykes and sluice gate maintenance, water supply sources. Moreover, other measures also support to protect the coastal zones by planting mangrove, fences or wave-breakers. It is estimated about 2,310 billion VND (~110 million USD) to construct dykes in the Mekong Delta.
- ❖ Increase awareness of the climate change impacts for local farmers by regular training, posters, education, mass media and materials on policy/strategy: these activities should repeat regularly to assist local farmers try to plan or find appropriate solutions by themselves. For example, they can decide to move to another place or decide to "living with climate change". In the case of "living with climate change", they have to find suitable adaptive measures for themselves to live with impacts of climate change. DARD can play an important role in providing information and training to the farmer on the potential climate changes and their impacts. In addition, Institutions and Universities can assist and provide this training.
- ❖ Establish network of aquaculture extension officer: It is very necessary to establish networks of aquaculture extension officers to support local shrimp farmers, especially on farm. Officers in the network act as technical persons in shrimp farming, they are the key persons to assist shrimp farmers, particularly in diseases bloom, so that they can give appropriate advice to deal with each problem.
- ❖ Establish shrimp clubs/cooperatives/associations: the fact shows that water management is a key issue in shrimp farming as waste water from farming system and water supply is not separated. As a result, a farm/pond infected with disease and lost production can also cause other close farms infect by exchanging water. This leads to conflict among farmers. Generally, an agreement (regulations) of each co-operative or club is prepared, agreed by all members and released to implement. All members are asked to comply with this agreement. Representatives from local authorities and unions/NGOs should support for club/cooperatives, especially at the beginning of the establishment. Moreover, other trainings such as shrimp farming, organizational management skills, and alternative likelihoods (livestock and agriculture). Farmers clubs/cooperatives/associations need to be clustered and reorganized, to provide places (like a "public room" or "local library" for displaying information and materials and discussion) for sharing experiences and information on shrimp aquaculture activities as well as weather forecast and crop seasons. RIA2 has many experiences in establishing and operating club and cooperatives in participatory water management in shrimp farming under support of MRC in Sóc Trăng provinces.
- ❖ Establish shrimp disease inspection and water monitoring centre: quality of shrimp seed and water should be inspected and monitored regularly, then inform/advise farmers in order for them to decide their crop or farming system to be more appropriate. DARD can associate with RIA2 as RIA2 has been established a network of water monitoring station in the Mekong Delta and has disease inspection division. Moreover, it needs to monitor the use of chemicals, commercial feeds and probiotics in shrimp production.

- ❖ Establish new farming models and improve pond design: Present aquaculture production models need to be reviewed as adaptation will require new shrimp farming models to be developed to cope with more rain and high temperature and irregular weather events to improve profitability. Particularly, small-scale shrimp farmers should intensify their farming in a small area of their farm to improve productivity/profit, particularly to cope with climate change and limited reliance on the nature. This is considered only way for farmers to offset climate change. Provincial DARD together with Institutes and Universities need to recommend new models. Moreover, it is necessary to diversify more resistant species that can tolerate the predicted future climate change.
- ❖ Diversify livelihoods: it is important for diversifying farmers' income to increase local farmer's resilience to climate change. Training and related supports should be provided for farmers to improve income.
- ❖ Need to revise the current strategy for aquaculture development, and incorporate new measures into National Policy and Regulations. They need to develop institutional capacity to address impacts from climate change. These can then be passed to provincial DARD and other agencies for implementation.
- ❖ Enhance shrimp population in the wild: in fact, almost all hatcheries catch broodstock from the wild. Hence, the hatcheries should have a responsibility to enhance wild population of shrimp by releasing regular shrimp seeds into the wild. Local government should encourage local hatcheries owners or processing companies support this programme.

It is very important for the Central and local Government to re-allocate a reasonable budget to support activities above. In addition, climate change issues should be mainstreamed into local activities/programmes to strengthen supporting to farmers. Moreover, credit support programmes also need to establish to support farmers.

Policy brief: Policy options and framework

Four climate change issue were identified and contributed to major impacts on shrimp farming in the Mekong Delta: High temperature, Storms & typhoons, Sea level rise, and Rainfall. Farmers stated that "High temperature" is the most important factors influencing shrimp farming while Science and technology group claimed "Rainfall" is the most important (Table 57).

Table 57: Climate change issue ranking comparison between stakeholders

Climate change issue	Ranking by stakeholders	
	Farmers	Science and technology
High temperature	1	3
Storms & typhoons	2	2
Sea level rise	3	4
Rainfall in dry season (more often)	4	1

Farmers group:

The main climate change issues for the farmer group were high temperature (32.0%), storm and typhoon (26.3%), sea level rise (26.2%), and rain fall in dry season (15.5%).

- High temperature (1st): adaptation measures are identified: (1) Change surface water (36.2%); (2) Make pond deeper (26.8%); (3) Increase pond dike height (19.7%); (4) Make ditch wider (17.2%).

- Storms & typhoons (2nd): adaptation measures are identified: (1) Improved pond dike: wider and stronger (38.5%); (2) Use probiotic to improve water quality (31.3%); (3) Improve sluice gate (30.2%).
- Sea level rise (3rd) : adaptation measures are identified: (1) Improve pond dike: wider and stronger (35.3%); (2) Improve forecast information/monitoring (33.9%); (3) Use net to prevent shrimp escape (16.4%); (4) Use water pumping machine (14.4%).
- Rainfall (4th): adaptation measures are identified: (1) Use lime to adjust water quality (50.4%); (2) Change water surface (33.0%); (3) Use aerator (16.6%).

Science and technology group:

- Rainfall (1st): adaptation measures are identified: (1) Best Management Practice (49.0%); (2) New pond design (28.7%); (3) Seed quality control (22.3%).
- Storms & typhoons (2nd): adaptation measures are identified: (1) Accurate weather forecast (50.6%); (2) Planting mangrove for coastal erosion protection (25.6%); (3) New pond design: dike strengthening (23.8%).
- High temperature (3rd) : adaptation measures are identified: (1) Best Management Practice (55.5%); (2) New pond design (24.1%); (3) Crop calendar management (20.4%).
- Sea level rise (4th): adaptation measures are identified: (1) Planning and zoning for rice and shrimp culture (42.1%); (2) New pond design (36.1%); (3) Salinity tolerance species (21.9%).

Policy and institution group:

The most preferred adaptation measure was training of farmers and extension workers (42.9%) followed by more funding for improving infrastructure (dike and sluice gate maintenance) (24.3%), need for standard routines for monitoring shrimp farms (19.5%), and establishing shrimp cooperatives (13.3%).

Technical brief – Farmer

a. Site selection and pond construction under climate change impact

- Correct site selection for aquaculture zone
- Separate water inlet supply and effluent discharge systems to the zone
- Separate water inlet and outlet systems in the ponds
- Suitable soils
- Suitable water quality
- Sufficient pond water depth
- Inlet water treatment area
- Effluent water treatment area
- Physical or natural buffers between different safe aquaculture zones
-

a1. Site selection

The safe aquaculture zone should be in a well selected site. For example if the water quality is poor with high siltation from rivers, rapid changes in salinity, or poor replenishment of water then shrimp will be stressed and more susceptible to disease, Even if biosecurity is enforced in the zone the zone will always be more vulnerable to disease outbreak.

Water replenishment
The replenishment of water or residence time in the water body is important for dilution of nutrients in the effluent from the ponds, the background bacterial levels and water quality for filling and water exchange in the ponds.

Water quality
Shrimp production depends on a supply of good quality water and maintaining good water quality in the ponds. If water quality is poor or variable, there is a risk to growth, health and survival. In many areas there is increasing risk of poor water quality due to urbanisation, industrialisation and from increasing aquaculture development.

Salinity
Shrimp do not respond well to sudden changes in salinity, and rainfall patterns have become more erratic, with increased rainfall for example in the dry season. Furthermore, erratic heavy rain may result in poor water quality (runoff from upstream). This represents a significant risk for producers by causing stress to the shrimp making them more susceptible to disease. Farms that are located in areas with changeable salinity will tend to suffer increased disease incidence.

Temperature and temperature fluctuation
Sites that are at the extremes of the temperature range for optimal growth (too hot or too cold) or suffer from wide temperature fluctuations (hot days/cold nights) will also be problematic for production. This tends to be more pronounced when the water is taken from a shallow waterbody.

Number and intensity of farms in the area
There is increasing risk of poor water quality and disease outbreak due to increasing number and intensity of farms in the area.

a2. Zone and pond design
The safe aquaculture area should be planned and designed before the pond development starts. It is often more expensive to modify pond or farm design after it has been built and is operational than planning correctly in advance. However planning pond layout, pond water supply and treatment needs to be flexible to allow for changes in culture species to allow adaptation to shifting market conditions.

Separated inlet and effluent water supplies and water treatment
The concentration of shrimp farms in an area means that transfer of disease between farms through the water supply is likely. The level of risk is higher in areas where the density of farms is highest and where water intakes and effluent outputs are to the same water body.

There are three ways to address this problem

- The separation of water inlet from outlets
- The treatment of inlet water
- The treatment of effluent water

Inlet water treatment area
The use of supply water reservoirs and water pre-treatment is relatively common for intensive production, but remains rare for improved-extensive systems and is often non-existent for extensive producers. It should be a standard practice in all improved-extensive and intensive systems.

Effluent water treatment area
In shrimp culture, waste loading comes from two sources: shrimp feed and shrimp excretion. These organic wastes and nutrients consist of solid matter (mainly uneaten feed, faeces, and phytoplankton) and dissolved metabolites (mainly ammonia, urea and carbon dioxide). Uneaten feed and excretory products sinking directly onto the pond bottom can have a significant effect on the sediment quality and on the health of shrimp living there.

Aquaculture wastes that are discharged to receiving water have a measurable impact to the environment. Thus, aquaculture activity is focusing its attention on development of technologies for improvement of effluent quality and pollution loading. In most cases, a significant fraction of the biological oxygen demand (BOD) and organic nitrogen waste can be removed with simple settling technology.

An effluent sedimentation area is required particularly for higher intensive production. Most intensive shrimp farmers have settling ponds however few semi-intensive producers use sedimentation ponds. Extensive systems pose no significant threat to water quality in the wider environment. Farmers can use either a common sedimentation area or zone or have their own sedimentation area for effluent water. Depth of the sedimentation area should be one meter. To reduce the organic load of water, it is recommended to culture bivalves and seaweed in the sedimentation area to strip excess nutrients from the water

Effluent water may be discharged to the environment under gravity. Minimum sedimentation area is 10% of farm operating area.

b. Implementing safe aquaculture practice
Implementing safe aquaculture practice should be undertaken by implementing biosecurity measures and good aquaculture practices.

Biosecurity - Reducing risk of disease
Control of
- Water supply and quality
- Disease carriers (wild shrimp and crabs)
- Disease free post larvae
- Shrimp feed (home made feed)

Environment
- Reduced nutrient effluents to the environment
- Reduced water exchange
- Prevention of salination of groundwater
- Prevention of impact on sensitive habitats and species

Food safety
- No use of banned medication or chemicals
- No use of antibiotics

- Implement correct withdrawal time
- Hygienic harvest and post harvest
- Maintain cold chain

b1. Participation

Every farmer in an aquaculture zone should participate in the implementation of biosecurity and safe aquaculture practice. If one of the farmers does not conform and stocks diseased seed, then all the other farmers are at risk and it is not a safe zone.

b2. Operational planning

There are some management practices that can minimise disease outbreaks

Crop calendars and seasonal planning

In many cases the outbreak of disease is seasonal. Temperature is an important factor, as *Penaeus monodon* is more susceptible to WSSV at lower temperatures. Whilst the weather pattern may vary from year to year, it is therefore desirable for farmers to stock shrimp avoiding high-risk periods. Crop calendars which are linked to long range weather forecasts can be developed to help with the optimal time for stocking.

Disease prevention and control plan

General biosecurity precautions need to be established in each zone to help support the activities of both disease prevention and disease control. A short manual of standard operating procedures (SOP) should be prepared by the safe aquaculture zone management committee to provide a set of standard rules and guidelines for biosecurity measures and disease monitoring.

The manual should include such things as

- zone map with pond and owners,
- water flow system Inlet and outlet,
- rules for limited or restricted visitor access to zone,
- visitor log book,
- disinfection procedures for pond water,
- disinfection procedures for shared equipment,
- a sludge disposal plan,
- pest control guidelines (crabs),
- general safe husbandry and management procedures.

This manual should also incorporate procedures to be followed if a disease is detected or an outbreak occurs. Record keeping is important to the success of any biosecurity program because it can provide accurate historical information about the health status, weight gains, feed consumption, treatments, and management practices of the ponds and zone.

b3. Operation measures – Hatcheries

Hatchery Operations

Few hatcheries supply many farmers and so it is easier to target the hatcheries and encourage them to supply disease free fry rather than target the many small scale farmers to buy disease free seed. Biosecurity measures that should be introduced to hatcheries include

- Tanks for water storage and inlet water filtration and disinfection.

- Effluent treatment tank.
- PCR testing for WSD and MBV before receiving breeders to the hatchery to ensure that breeders are free from WSD.
- Breeders should be kept in the quarantine tank until test results are known. If the breeders are infected with WSD, they have to be treated or destroyed
- Post larvae should be subjected to screening by PCR for every cycle so that a whole batch produced by the hatchery is represented to ensure that each batch is free from WSD and MBV (level of <5 %). If any disease is found, the hatchery should be chlorinated and kept closed for a minimum of at least two weeks
- After every two or three operational cycles, hatchery should be kept closed at least for two weeks and the hatchery disinfected and dried out.

The hatcheries should be encouraged to maintain Specific Pathogen Free (SPF) broodstock that are held in biosecure facilities and are routinely checked and found to be free of specified pathogens.

Due to the disease problems in broodstock collected from the wild and the periodic low quality and shortage of wild *Penaeus monodon* broodstock, there is a need for the selective breeding and development of domesticated broodstock. The development of such alternative sources of broodstock would also help to improve maturation and spawning success and limit the high price of broodstock during the seasons of highest demand.

Advantages of using domesticated and SPF stocks include:

- ready, year-round availability of disease-free broodstock;
- the ability to be selected for desirable traits such as fast growth rate, disease resistance and hence high survival, good FCR and increased production and productivity;
- reduced use of chemicals and treatments
- better adaptability of domesticated shrimp to captive environments, leading to reduced stress and better mating and reproductive success; and
- increased traceability of the origin of stocks and their past performance and future potential.

Currently there are a number of programmes aimed at producing domesticated stocks of disease-free *P. monodon* broodstock in Thailand and in Hawaii, United States of America (FAO, 2005). In Thailand there are hatcheries operating solely with domesticated broodstock (now 5th generation) held in ponds with water conditioning and treatment systems.

Seed – Poor quality

Seed quality is a key issue in shrimp production and can be problematic especially for small scale producers.

Poor seed quality may result in:

- Poor growth
- Poor FCR
- Vulnerability to disease and poor survival
- Poor quality product

Small-scale farmers are particularly vulnerable to poor quality seed due to their lack of awareness of the potential problems with poor quality seed. They are more inclined to buy cheap seed or there may not be hatcheries producing high quality seed in their area.

It is essential to test post larvae quality before stocking. Observations should be made on activity, colour, size, etc. from the selected tanks in the hatchery.

Specific Pathogen-Free (SPF) seed
Bringing new shrimp into the farm usually presents the greatest risk of introducing infectious disease.

One of the main ways to avoid the introduction of disease into the farm is to purchase shrimp/post larvae from a producer selling specific pathogen-free (SPF) seed. Though this does not eliminate all potential diseases in the seed supply, it does help reduce the risk of introducing the major pathogens of shrimp.

The farmer should check the quality of post larvae and if they are found to be good, post larvae should be tested for WSD by PCR screening. If the WSD disease is not found, stocking of post larvae could be carried out. If required, either pre growing ponds or Hapas could be used as nursery grows out tanks. Post larvae could be grown 1 month in these nursery facilities before releasing to the grow-out pond.

In order to achieve this, the hatcheries should be encouraged to establish domesticated in-house brood stock and spawning facilities.

b4. Operation measures – Pre-stocking
A number of measures have been identified that can significantly reduce the risk of disease outbreaks and improve shrimp production.

- Removal of bottom sludge, particularly in ponds stocking higher densities.
- Ploughing of soil when wet.
- Use of lime in pond preparation.

There are management practices that can be adopted to reduce risk factors associated with pond filling and preparation of water before stocking. These include:

- Water filtration (mesh of 60 holes/sq inch) reduces the risk of disease outbreak through reduced introduction of carriers to the pond.
- Disinfection of pond water can also reduce the risk of disease outbreaks in farms using higher stocking density (such as Nellore district).
- Fertilization reduces the risk of disease outbreak in lower stocking density farms.

Pond preparation
Pond preparation is essential to reduce risks of shrimp disease outbreaks. Shrimp ponds with a history of disease outbreaks have a greater likelihood of future disease outbreaks; therefore special attention is required during pond preparation in such farms. Farms with poor bottom soil quality, particularly the presence of a black soil layer, will suffer crop failures.

There are certain key pond preparation measures that are necessary to improve pond bottom conditions.

- Organic matter in the pond bottom should be removed even whether it is wet or dry. This sludge must be removed as if it left by the side of the pond (where it may drain back into the pond) it may constitute a risk to shrimp health.
- Lime is recommended to be used according to pH of the soil.
- Fertilizing of the pond is recommended according to the fertility of the pond soil

Pond disinfection
An important area of disease prevention and control that is often overlooked in the aquaculture industry is disinfection. Ponds (and water filling the ponds) can be disinfected by adding chlorine to the pond bottom just prior to filling the pond.

Quarantine during nursery
In addition to disease avoidance, a quarantine program should be implemented to isolate any new seed arrivals to the aquaculture zone into a separated nursery pond. The seed should be nursed separately for a minimum of 30 days. During this time, the shrimp should be monitored for signs of disease, sampled for disease testing after 30 days and if found to be free from disease then stocked into grow-out ponds.

b5. Operation measures - ongrowing
Optimal management techniques, including stocking densities, nutrition, and genetics are essential for all aquaculture species to develop and maintain optimal health and resist disease.

Maintaining good water quality during on-growing
Poor water quality may lead to loss of condition, stress, disease, low survival, and poor food conversion.

There a number of water management measures that can be taken to reduce risk of disease outbreak. These include:

- Water exchange practices – in ponds exchanging water to maintain water quality improves shrimp production.
- Water filtration - ponds using water filter nets of fine mesh have better production.
- High pH (>8.5) has an effect on the risk of disease outbreaks. In cases where pH exceeds 8.5, the toxicity of ammonia increases leading to higher stress conditions for shrimps.
- High salinity has an affect on the risk of disease outbreaks. In high saline waters it is difficult to maintain water quality, especially to maintain a stable microalgae bloom compared with that in low saline waters. Therefore, the stress on shrimp due to changes in bloom conditions may make them more susceptible to viral infection and subsequent disease outbreak

There is also a significant relationship between shrimp disease outbreaks and micro-algae and macro-algae in the ponds:

- Ponds with clear water at stocking and during the culture cycle are at risk from lower production and shrimp disease outbreaks.
- Green water (pond colour) ponds have better production and lower risk of disease outbreaks.
- Clear water with benthic and filamentous algae lead to lower production.
- Ponds with dead benthic algae observed during culture are at risk of disease and poor production.

However many household scale producers have limited options in terms of water supply and exchange, and may lack the means to treat incoming water, or effectively remove sediments between cycles.

Water used for filling the pond should be filtered through a fine mesh screen to filter crustacean, fish eggs and wild fish etc.

Feed quality and safety
Quality of feed (especially home made feed) is an issue, especially for smaller scale shrimp farmers. The consequences of using poor quality feed intentionally or unintentionally may be serious in terms of:

- Poor FCR
- Slower growth
- Poor condition/quality
- Susceptibility to disease

There are risks of disease transfer from home made feed to the shrimp if incorrect raw ingredients are used. If fresh feed ingredients such as snail or trash fish are used during the later stage of the cycle to improve growth, it should be only under close monitoring of water quality and a careful feeding strategy to avoid wastage. If possible it should be cooked to reduce risk of disease transfer. In no case should crustacean based ingredients be used in home made feed.

Farmers should monitor daily feeding in order to prevent excess feeding. A feeding record should be maintained at the farm to be used for monitoring purposes.

Accumulation of pond sediments
The occurrence of black and toxic bottom sediments has been shown to adversely affect shrimp health and lead to disease outbreak or poor production. The organic matter which accumulates in shrimp ponds is likely to harbour some diseases, and especially parasites. Complete emptying of ponds, drying, discarding or ploughing and disinfecting can eliminate most disease organisms.

Serious accumulation of sediments in ponds becomes a problem with more intensive forms of shrimp farming. Viral disease can probably survive in most ponds between crops unless there is significant fallow and pond bottom treatment. Household scale producers may find it more difficult to empty, dry and treat ponds, and there is therefore greater potential for pathogen accumulation.

There is a widespread and well documented tendency for growth and productivity in shrimp ponds to decline through time, and this may well be related to accumulation of toxins and disease organisms in pond sediments. Chronic disease in shrimp remains a major problem, and may be in part attributable to poor sediment treatment and management.

Possible management measures include

- Single crop with long fallow.
- Sediment drying and sterilization
- Sediment removal

Sludge removal
Cleaning the pond bottom is a very important pond preparation activity. The soil should be checked for the presence of black layer when it is in wet condition. If the soil is completely dried then the black layer will turn to a lighter colour due to oxidation, making it difficult to recognize that black layer in the soil. It is easy to remove the sludge when the soil is dry.

The sludge must be disposed of away from the pond site, so that it does not seep back into waterways, ponds, or cause other environmental problems. In farms with lower stocking densities, it may not be necessary to remove the sludge, unless there was disease outbreak during the last crop. In such a situation extra precaution should be taken. If the sludge is removed properly then management of the pond becomes easier during high pH periods, a common problem in areas with low salinity, and high plankton growth.

Sludge removal should pay attention to areas of the pond where there is a high accumulation of organic matter from previous crops, such as feeding areas, and the side ditches in extensive farms. Sludge has been found to be a good fertiliser especially for trees.

Ploughing
The main purpose of ploughing is to expose the black soil layer(s) underneath the bottom soil to sunlight and atmospheric oxygen. By this process, the organic waste (sludge) will be oxidised.

Presence of moisture in soil (*i.e.*, under wet soil conditions) during ploughing allows bacteria to work better in breaking down the black organic matter, thus making the ploughing process more effective. Ploughing on wet soil is particularly recommended when the sludge cannot be removed properly by manual or mechanical methods.

After ploughing, the pond bottom is dried for 5 to 7 days and the procedure repeated until no more black soil is seen.

The pond bottom soil should be checked on weekly basis, especially at the feeding area or trench. The occurrence of black soil, benthic algae and bad smell should be recorded. If the soil is black and smelly, water exchange should be carried out and feed reduced (using a feed tray to monitor requirements).

Disease carriers
Disease in carriers such as crab and wild shrimp is a significant and probably increasing risk for the transfer of disease. Diseases such as whitespot may well be widespread in wild crustaceans such as crabs.

This can be addressed by the following measures
- Filtering water intake water using a net of more than 60 holes/inch mesh (425 microns) that will prevent small shrimp or crab from entering
- Trapping wild crab
- Erecting crab nets between ponds

Equipment disinfection
There is risk of transferring disease between ponds through equipment that has not been disinfected between use. However, having separate equipment (nets, feed buckets, water

sampling jars, etc.) for each production unit would be optimal in helping to eliminate the risk of contamination between production systems.

Equipment that has been in contact with shrimp from outside of the safe zone can spread diseases. To help minimize this risk, the farm equipment should be washed and disinfected before use.

- Nets should not be shared between farms unless thoroughly cleaned and disinfected.
- Equipment should be cleaned and disinfected between uses.

Vehicle disinfection
There is a risk of transferring disease between safe zones by vehicles especially vehicles transferring stock or equipment between farms or other facilities. Vehicle tyres and undercarriages should be cleaned with freshwater.

Visitors
When visitors to the farm are expected, consideration of relative risks allows you to develop and use practical biosecurity measures.

- **Low-risk visitors** - Visitors from villages or towns who have no contact with shrimp farms present very little risk of carrying diseases.
- **Moderate-risk visitors** - People who routinely visit fish farms but have little or no contact with the shrimp or culture water such as salesmen and delivery people present only a moderate risk of introducing disease.
- **High-risk visitors** - High-risk visitors include veterinarians, shrimp suppliers or shrimp buyers, neighbouring shrimp farmers, and anyone else who has close contact with shrimp or shrimp farms.
    - Visitors should wash their hands and feet.
    - Equipment and instruments that have direct contact with shrimp should be cleaned and disinfected before and after use.

Probiotics
Some farmers use bacterial products (probiotics) to improve water quality. The addition of beneficial microorganisms may play an important role in safe aquaculture practice. Positive aspects of microbes include

- their potential to provide additional nutrients thereby reducing feed costs
- their role in maintaining good water conditions within the culture environment by reducing the presence of stressors like NH3, NO2, NO3 etc,
- their potential to stabilise microbial levels in the water and reduce bacterial infections caused by Vibrio and other bacterial pathogens

There is some research that indicates that selected microorganisms such as yeasts and yeast products offer several benefits: improving feed attractability, supporting growth by producing vitamins, minerals, nucleic acids and by stimulation of beneficial gut flora.

However, there is limited scientific evidence as to the efficiency of such products and there is a need for more research and field trials on the use of probiotics.

Immunostimulants
Shrimp do not develop a specific immune response. However the immune response can be boosted by the use of immunostimulants.

The immunostimulatory property of yeast cell walls (β-1-3 glucan, lipopolysaccharides, and peptidoglycans) to induce short-term non-specific immune response in shrimp can improve the ability of the shrimp to resist infection.

Regular disease monitoring
Disease monitoring should be an essential part of any biosecurity program. This consists of regularly checking the health of the shrimp and testing for disease.

Although disease testing cannot completely guarantee that there are no potential pathogens in a shrimp population, it does help reduce the risk of maintaining a pathogen in a population. Periodic monitoring can also help determine the number of individuals within a population that are infected, and the level or intensity of infection within that population.

Disease treatment
If there is a disease outbreak in a particular pond, prompt action must be taken to prevent the complete loss of the crop and the spread of disease to other ponds.

If a farm is observed to be infected with a disease, the Safe Management coordinating committee should be informed, as soon as possible. In order to inform nearby farms, a red flag should be erected at the disease-infected farm. Water from infected ponds should not be released to the environment. Farmers should strictly adhere to this.

If the size of shrimps in the infected pond is above 5 g in weight, a drag net could be used for harvesting. The remaining stock should be destroyed by using appropriate concentrations of suitable chemicals. Dead prawns, shells, parts of the bodies should be buried. Treated water should be discharged after seven days.

During periods of disease outbreak, surrounding farmers should try to avoid water exchange and should not use any equipment (nets, tanks, pumps, boat, *etc*) from affected farms. The aim of this practice is to avoid any risk of cross contamination of the virus or other disease causing agents.

Antibiotics and medication
There should be minimal usage of chemicals and no usage of banned chemicals. This leads to reduced cost of production and prevents problems for marketing of the harvested shrimp in domestic and export markets.

There is serious concern about the use of antibiotics and the use of certain medication. Their use in shrimp farming should be avoided.

Harvesting
During harvesting, effluent water should be discharged to the sedimentation area to settle the organic load. Collecting prawns and transportation should be done hygienically in the best possible way.

Resting period
Ideally there should be at least 60 days rest period in between two culture cycles. Pond drying, removing organic load in the pond bottom, repairing dikes and canals, liming (if required) and fertilization (if required) can be carried out during this period.

Data recording
Keeping a pond daily record book helps to analyse the crop results, possible causes of disease, low yield etc. Also it helps to keep a check on crop related expenditures and income thus to improve the economic efficiency of the crop management by the farmer.

The following information on the farm operation should be recorded on a daily basis including;

- Pond preparation details
- Information on seed quality and quantity
- Hatchery name
- Date of stocking
- Treatments given to soil and water
- Water exchanges
- Feed quantity and type
- Numbers of observations made on any diseased or dead shrimps
- Water colour, pH, algae etc.
- Harvest date
- Harvested quantity
- Any other pond observations
- Expenditures on each activity and final income from sales.

Technical brief – Science and technology

The researcher should recognise the certification of safe aquaculture zones, register the names and details of the safe aquaculture zones and offer incentives for further safe aquaculture zones to be established.

❖ **Stages of implementation**
The cooperation of the hatcheries supplying the seed to farms is required to regularly test their output for disease and quality.

Hatchery supplier:

- **Quarantine area for newly caught broodstock.** The hatchery should have a quarantine area separated from the hatchery for the stocking of newly caught brooders.
- **Testing of broodstock for disease**. The breeders should be held in these facilities, tested for disease and if found to be disease free then they could be transferred to the hatchery for spawning. If they are found to be diseased they should be treated or destroyed.
- **Testing seed production for disease**. The hatchery should test each batch of seed for disease and only sell disease free seed to the farmers in safe aquaculture zones.
- **Testing for seed quality**. The hatchery should test the quality of seed in the presence of the farmer and only supply good quality seed to the farmers in safe aquaculture zones.

Producer:

- **Information dissemination**. The farmers should be informed of the concepts and principles of safe aquaculture in a participatory manner by extension workers or other technically qualified staff.

- **Discussion with farmers**. There should be discussions with the farmers on how to implement the safe aquaculture practices and to find out which farmers are willing to follow the safe aquaculture practice
- **Identification of safe aquaculture zone**. The technical staff should identify the safe aquaculture zone where all the farmers in the zone agree to participate. The boundaries of the zone should be identified.
- **Data collection**. The technical staff should undertake questionnaires of present aquaculture practice by the farmers in the zone as well as a sample of farmers outside the zone.
- **Workshop on safe aquaculture practice.** A workshop should be undertaken with the selected farmers and management committee to present the safe aquaculture practices that should be followed. A written manual of the safe aquaculture practices should be distributed to all participants
- **Setting up management**. A management committee should be set up comprising local leaders, representatives from the fishermen and fish farmer cooperatives, Women's union, etc.
- **Signage**. Signs should be erected at the edge of the safe aquaculture zone to identify the boundaries and request visitors not to enter without permission and disinfection. There should be foot baths at the main entrances to the zone.
- **Facilitated farmer field training.** There should be farmer field training undertaken to demonstrate pond preparation, pond water filling, and seed stocking techniques.
- **Safe aquaculture practice by farmers**. The farmers start to practice the safe aquaculture practices for seed selection, pond preparation, pond filling, feeding, pond management, disease treatment, harvesting, etc.
- **Monitoring and evaluating of implementation.** There should be a system of monitoring farmer compliance with the safe aquaculture practice. This could be undertaken by themselves, by monitoring each other's culture practices, or by regular visits to the ponds by a representative from the safe aquaculture zone management committee.
- **Minimum standards achieved by all farmers**. The safe aquaculture practices for the first culture season would initially be a form of Better Management Practices where better safe culture practice would be implemented. In this case the objective would be to improve the operational management. However during the second culture season, the safe aquaculture practice should be a form of Good Aquaculture Practice where compliance of culture practice is measurable against a minimum standard to be achieved. For example all seed should be tested for disease before stocking; All seed should be nursed in nursery ponds before stocking in grow-out ponds. Seed should be tested for disease before stocking in grow-out ponds, etc.
- **Application for certification**. Once all the cooperating farmers in the zone are complying with the safe aquaculture practices and everyone has achieved the minimum standards, they should apply for certification of the zone.
- **Checking certification compliance**. The Government should appoint an independent agency (it could be governmental for example the extension service or a private company) to check the pond, design and operational procedures and decide if they meet the minimum standards.
- **Awarding certified status**. If the minimum standards have been met then the zone should be awarded as a certified safe aquaculture zone. If there are certain criteria that have not been met, then they should be listed with recommendations on how to meet the criteria. The farmers should be given some time to make the necessary

adjustments. These criteria should then be re-inspected and the zone certificated or not.

- **Formalising the management committee.** Once the zone is certificated the management committee should be formalised as a legal body.
- **Auditing certification compliance**. Once the zone is operational, there should be yearly inspections to ensure that the minimum standards are maintained.

❖ **Managing safe aquaculture:**

Scientist help setting up a management framework for the safe aquaculture zone.

Agreement between farmers to cooperate and follow safe aquaculture practice

It is very important for farmers to discuss the farming situation of the zone at regular intervals and to maintain a close watch for disease outbreaks in the surrounding areas. Organising cooperating farmers in the safe aquaculture zone in a formalised farmer club/association/society would lead to many additional benefits, such as common stocking dates and seed to minimize seed selection and transport cost. Similarly, they can collectively purchase feed, lime, fertilizers and other commonly used inputs. This minimizes the cost of inputs and assures farmers on the quality of the product.

The farmers' clubs can also procure basic instruments for soil and water quality parameter analysis (like pH meter, DO meter, kits for ammonia, alkalinity, etc.) and even some simple health management kits. During harvesting time, farmers' groups can negotiate with buyers, bargain reasonably good prices for shrimps and also get a premium price for high quality, chemical residue free shrimp which gives an added advantage to the farmer in marketing its product. Thus, the farmer groups can play a very important role in managing the source water quality and the local environment.

In addition, these may also be associated with "forum support" – effectively group insurance or shared risk to support a farmer who gets disease. This may be contributed to by DARD disease prevention fund

Coordination committee overseeing implementation

Initially an informal safe aquaculture zone coordination committee should be established with representatives from the Commune, fishermen's and fish farmer's cooperative, women's cooperative, RIA2, extension service. This committee should meet regularly to facilitate the farmers in establishing the zone and following safe aquaculture practices. They should also be involved with the monitoring of farm to ensure that farmers are following safe aquaculture practice and to coordinate the monitoring of pond effluent quality, disposal of pond sludge, and other operations.

❖ **Encouraging safe aquaculture practice and zones.**

The farmers will not voluntarily form safe aquaculture zones unless they are persuaded in some way. This may be voluntarily or mandatory

Voluntary measures:

There are costs for the implementation of safe aquaculture practice or development of safe aquaculture zones. If the farmer can be convinced that by following the safe aquaculture practice and establishing a safe aquaculture zone, there will be less disease outbreak and better profitability, then they may take up the concept voluntarily.

Other ways to encourage uptake are as follows;

Better safe management practices (based on BMPs):
These are guidelines that encourage the farmer to improve operational practice taking into consideration biosecurity, protection of the environment and food safety. These BMPs should cover;

- Pond preparation
- Seed quality and stocking
- Feed and feeding
- Water management
- Pond management
- No banned chemicals
- Harvesting and post-harvest

The implementation of BMPs has been successful in many other countries and lessons learned from these experiences are given in section 6.

Good safe aquaculture practices (based on GAPs):
These are measurable standards that the farmer must implement above a minimum acceptable level. These GAPs should cover standards for;

- Pond and zone location:
- Pond and zone design
- Disease testing
- Inlet water quality control
- Feed quality
- Chemical and medication use
- Biosecurity
- Effluent quality and disposal
- Sludge disposal

Safe Shrimp Culturing Certification
There are a number of safe certification schemes that could be developed.

- Safe shrimp culturing zone
- Safe intensive shrimp culturing farm
- Food safety for cultured Shrimp

Mandatory measures:
The implementation of safe aquaculture zones could also be made mandatory. This is more appropriate to developing disease free hatcheries, better quality of feed or to farm areas that are at particular risk from disease.

Government regulations and legislation
The government could apply legislation of regulations to force the implementation of safe aquaculture practice or zones. However if this was the case then there should be at the same time some incentives available for the farmers to comply in order to help cover the additional costs or work involved.

Commune regulations

Safe aquaculture practice guidelines could be implemented at the community level particularly in communes where the shrimp farmers are suffering disease outbreaks on a regular basis. This would require capacity building at the community level from Provincial and Central government levels.

Control of safe aquaculture practice:
If the implementation is through regulation or legislation, then there should be sufficient inspectors to check compliance.

If the implementation is voluntary, then it is more difficult to control compliance. However, there are a number of possible ways to try and control compliance.

***Peer pressure*:** If the farmers are cooperating strongly and the coordination committee monitoring progress, then peer pressure from the other farmers may be sufficient to ensure that all famers are following the safe aquaculture practice.

Fines (Paid into a disaster fund): A system of small fines for not following correct safe practice could be introduced and implemented by the coordinating committee. These fines should be held in a disaster fund to assist farmers who suffer problems through no fault of their own (storm damage, floods, etc).

Expulsion from association/group: A possibility would be the expulsion of the non-complying farmer from the aquaculture zone. However this is difficult as all farmers in the zone must comply otherwise it is not a safe zone. Therefore this is not possible unless the ponds are on the edge of the zone and the zone can be reduced in size with out compromise the safe operation of the remaining ponds.

Withdrawal of certification: If a farm or a zone has been certified, but the farmers do not continue to apply the safe aquaculture practice, then this should be noted at the regular inspection and the details given to the farmers on how to achieve the required standards. Upon re-inspection, if the standards have not been achieved then the certification for the safe aquaculture zone should be withdrawn.

Outcomes of Safe Aquaculture Zones and practice:
The outcomes of applying safe aquaculture practice and having safe aquaculture zones are economic, social, environmental and food safety.

Social benefits

- There should be improved livelihoods due to the reduction in disease leading to improved survival, improved productivity and associated profits.
- The formation of safe aquaculture zones with cooperation between farmers and coordination committee members should lead to stronger community harmony

Economic benefits

- Improved productivity. As mentioned above reduction in disease will lead to improved profitability and better economic viability of the pond.
- Certification for safe aquaculture zones could lead to improved market prices for a product that is recognised safe for the environment and safe to eat.

Environmental benefits

- There will be reduced impact on the environment due to
    - The use of effluent treatment ponds,
    - good pond management which will prevent the build up of anoxic sludge on the pond bottom
    - reduced use of medication that might be released to the environment or accumulate in the pond sediment

Food safety benefits

- Less disease outbreaks results in less chemicals and medication used and this will improve food safety of the product.
- Following best safe practice on harvest and post harvest practice will ensure that the cold chain is maintained from the harvest to the consumer.

Annex 3: Other Climate Change Projects

❖ Impact of climate change and adapting bio-security measures for aquaculture in Northern Vietnam (ICA)

Project period : 2011 – 2014

Sponsor : DANIDA (Implemented by RIA1)

Location : Northen Vietnam

Objective : Assess the impacts of climate change on infrastructure, environment and biosecurity of major aquaculture systems of Northern Vietnam and Propose and disseminate mitigation measures of climate change for major aquaculture systems of Northern Vietnam to authorities, farmers and other stakeholders.

❖ National Target Programme on Climate Change

Project period : 2009 – 2015

Sponsor : Vietnam Government (Implemented by MORE)

Location : Vietnam

Budget : 143,878,788$

Objective : The strategic objective of the programme is evaluating the degree of impacts of CC on sectors and locals in each period and developing practically action plan to respond effectively to CC both in short and long terms to ensure the country's sustainable development.

❖ Climate Change Initiative Framework of the Mekong River Commission

Sponsor : Australia/AusAID (Implemented by MRC)

Project period : 2009 – 2015

Location : Mekong Delta

Budget : 4,000,000$

The Climate Change and Adaptation Initiative (CCAI) is a collaborative regional initiative of the Mekong River Commission, funded by AusAid, designed to address the shared climate change adaptation challenges of Lower Mekong Basin countries. The Regional Synthesis Report (RSR) from ICEM has been prepared as part of the initial phase of the CCAI to provide a snapshot of current knowledge and activities related to climate change in the LMB countries.

❖ Capacity building for climate change:

Project period: 2009 – 2012

Sponsor: United Nations Development Programme (UNDP)

Location: Vietnam

It is the key role and challenge for the CBCC project to assist and support MONRE and other key implementing agencies at both national and provincial level in developing the human, institutional and technical capacities to handle the climate adaptation and mitigation challenges. Objective of the project is to facilitate effective NTP implementation by strengthening the capacity of the implementing parties in the following areas: (1) Climate change policy and action plans formulation and incorporation of CC in relevant programmes/policies to improve: institutional framework for NTP implementation, CC mainstreaming in national policies and action plans, CC mainstreaming in provincial action plans and project implementation; (2) Enhancement of knowledge and research capacity for CC vulnerability, adaptation and GHG mitigation assessment for: CC impact and vulnerability, CC response measures, CC research programs, CC awareness raising; (3) Capacities strengthening for policy development and implementation of response measures for CC adaptation and GHG emissions control in: CC adaptation and mitigation.

❖ Strengthening national capacities to respond to climate change in Vietnam, reducing vulnerability and controlling GHG emissions

Project period : 2008 – 2012

Sponsor : UNDP (implemented by Vietnam Government)

Budget : 4,660,000 USD

Location : Vietnam

Implementing agencies are "MARD, MONRE". To develop frameworks, mechanisms and capacities in place to inform, guide and coordinate (i) analysis of climate change related risks and formulation of CC adaptation policy responses and investment plans; and (ii) analysis of Green House Gas emissions, and formulation of investment plans and ways to change consumer behaviour for low-carbon economic development.

❖ Capacity building for responding to salt intrusion due to climate change in Cần Thơ

Project period : 2012 – 2014

Sponsor : Institute for Social and Environmental Transition (ISET)

Budget : 521,414 USD

Location : Cần Thơ province (Mekong Delta)

Objective : Establish network monitoring of salinity; Increase awareness on impacts of salt intrusion; Recommend adaptive measures; Pilot model of “Storage freshwater against brackish water”.

❖ Netherlands funds climate change project in Long An:

Project period : 2012 – ????

Sponsor : Netherlands

Budget : 365,000 Euros

Location : Vam Co River basin (Mekong Delta)

Objective : The project aims to assess current climate change impact and make future forecasts. It will also review the effects of different measures against inundation due to floods and tides, as well as losses caused by salt intrusion.

- ❖ Denmark funds for 4 climate change projects

Project period : 2012 – ????

Sponsor : Netherlands

Budget : 18 million Danish Kroner

Location : Vietnam

The four projects include: Impacts of climate change on the change in land use and public livelihood in the Red River Delta, assessing impacts of climate change on nature, environment and socio-economic development in the central Centre of Vietnam, creating new rice varieties that can grow in deeply-flooded saltwater areas in response to possible high tides in Vietnam's coastal plains and climate change and ecological systems at the river mouths in Vietnam.

- ❖ Regional Climate Change Initiatives

Sponsor : USA/USAid

Location : Vietnam

Initiative will include the multilateral and bilateral programs/ projects in Vietnam likely focus on adaptation. In November 2008, the road map was being finalized for this possible initiative. State departments are also considering an adaptation-focused multi-million dollar regional program.

- ❖ Potential eco-social impacts of CC in Vietnam

Sponsor : UNEP (Implemented by MORE)

Location : Vietnam

Budget : 50,000$

Potential eco-social impacts of CC in Vietnam – impacts of CC on agriculture, health, production, energy, coastal forests and areas planning.

- ❖ Possible Development Policy Lending (DPL) on Climate Change as support to NTP

Sponsor : Japan/ODA

Under consideration in early 2009

- ❖ Helping poor farmers in rice-based systems in the Mekong delta of Vietnam adapt to climate change

Sponsor : Australia/AusAID (implemented by ACIAR)

Project period : 2009 – 2013

Budget : 1,000,000$

- ❖ Climate-proofing development in coastal areas

Sponsor : WWF

Project period : 2008 – ????

Location : Cà Mau

The project is to produce climate change assessments for Cà Mau Province and to promote greater consideration of these issues among policymakers and stakeholders by recommending changes in policy, planning, and institutions that could help with adaptation with Southern Institute of Water Resources Planning. Also in Krabi Province (Thailand) with the South East START Regional Centre.

❖ Vietnam Coastal Wetlands Protection and Development Project (P042568)

Sponsor : World Bank (Implemented by MARD)

Project period : 1999 – 2007

Location : Mekong Delta

Budget : 39,100,000$

The Coastal Wetlands Protection and Development Project, funded by the Government of Viet Nam, Danida and the World Bank, will re-establish the coastal mangrove wetland ecosystems along the Mekong delta for sustainable coastal protection. The project sets out to re-establish and protect a vital natural resource (the coastal mangrove forest), and to help poor people, who currently depend on the forest, to move from the full protection zone, resettle in the buffer zone, and gain more sustainable livelihoods.

❖ Climate Change assessment in Cà Mau Province Project

Sponsor : WWF

Location : Cà Mau

To better understand the implications of climate change for people and places in coastal Vietnam.

❖ Mekong Delta Climate Change Impact and Adaptation Project

Sponsor : ADB (Implemented by ICEM)

Project period : 2008 – 2010

Location : Mekong Delta

Also funded by AusAid ($1.14 million 2008-2010). Also implemented by MONRE (IMHEN). Will assess the impact and vulnerability of climate change in the Mekong Delta and propose practical recommendations for adaptation and mitigation and integration into development planning.

Annex 4: Questionnaire

QUESTIONNAIRE ON FARMER PERCEPTIONS OF CLIMATE CHANGE IMPACTS TO SHRIMP FARMING IN VIETNAM

AQUACLIMATE PROJECT

Definition of climate change: *Climate change is a significant variation in the mean state of the climate or its variability, persisting for an extended period (typically decades or longer)* **(IPCC)**

Respondent name:______________________________ Phone number:________________

Interviewer name: ______________________________ Date: ________________________

Commune:	**District:**	**Province:**
GPS READING AT SLUICE GATE UTM	**N**	**E**

PART A: SOCIO-ECONOMIC PROFILE OF THE RESPONDENT'S HOUSEHOLD

A1	Respondent status ( ) 1. Owner operator ( ) 2. Caretaker ( ) 3. Other;__________
A2	Age:
A3	Gender ( ) 1. Male ( ) 2. Female
A4	Ethnic group:
A5	Number of household members:_________ (Male:__________, Female: __________)
A6	Number of household members involved in farm: ______ (Male:______, Female: ____)
A7	Number of household members who earn income: _____ (Male:______, Female: ____)
A8	Respondent's main occupation (based on time spent):
A9	Different sources of respondent's household income in VND/Year ( ) 1. All farm activities: _____________ ( ) 2. Fishing: __________________________ ( ) 3. Trading: _____________________ ( ) 4. Hired labour ______________________ ( ) 5. Others: specify:_____________________________________ VND/Year
A10	Number of years in shrimp culture of respondent:
A11	Level of education of the respondent ( ) 1. Primary:_________ ( ) 2. Secondary: ________ ( ) 3. Tertiary: __________

PART B: FARM INFORMATION

B1	Number of shrimp farms owned by the farm owner:								
B2	Type of improved extensive farm (visited farm) (can choose more than one)								
	( ) 1. Shrimp	Species:							
	( ) 2. Rice	Species:							
	( ) 3. Fish	Species:							
	( ) 4. Crab	Species:							
	( ) 5. Others:	Species:							
B3	When was the visited farm established as a shrimp farm (Year)**:**								
B4	Visited farm land ownership ( ) 1. Owned ( ) 2. Leased								
B5	Total area of visited farm (all farm area) (Ha):								
B6	Number of shrimp ponds of visited farm:								
B7	Shrimp pond information of visited farm (if no ditch answer 1,2,3 and for 4 & 6 use bottom of pond instead of bottom of ditch)								
	Pond No.	(1)Pond area (ha)	(2)Length (m)	(3)Width (m)	(4)Height of dyke (bottom of ditch to the dyke top) (m)	(5)Height (bottom of ditch to the rice area) (m)	(6)Height of **water level** from the bottom of the ditch (m)		(7)Width of ditch (m)
							No rice	Rice	
	1								
	2								
	3								
	4								
B8	Do you have outside dyke? ( ) 0. No ( ) 1. Yes, If yes, How high _____ (m) for what purpose?_________________ ____								
B9	Source of water supply in visited farm (Specify % of the total amount (total =100%)) (%) 1. Canal (%) 2. River (%) 3. Estuary (%) 4. Sea (%) 5. others: specify:______________________________								
B10	Method of getting water into visited farm (Specify % of the total amount (total =100%)) (%) 1. Gravity/tidal (%) 2. Pumping by using ( )1 diesel ( )2 bio-gas ( )3 electricity ( ) 4 other:______ (%) 3. others: specify:_________								
B11	Are there systems of inlet water filtration and sedimentation in visited farm? ( ) 0. No ( ) 1. Yes: specify,______________________________								

B12	What is the salinity of inlet water? In dry season: _______________ ppt, In wet season: ___________________ppt
B13	Changing water (renew culture water) during culture ( ) 0. No ( ) 1. Yes: In wet season: ___________(%), In dry season: _______________ (%), In wet season pumping out to compensate for rainfall only _________(%)
B14	Do you use aeration in the pond? ( ) 0. No ( ) 1. Yes, specify (e.g., paddy wheel): ____________________________ If yes, how is it powered? ( )1 diesel ( )2 bio-gas ( )3 electricity ( ) 4 other:_________
B15	Is there a system of waste water treatment in visited farm? ( ) 0. No ( ) 1. Yes: specify, _________________________________
B16	Method of getting water out of the visited farm? (Specify % of the total amount (total =100%)) (%) 1. Gravity/tidal (%) 2. Pumping by using ( )1 diesel ( )2 bio-gas ( )3 electricity ( ) 4 other:______ (%) 3. others: specify:________
B17	Where does the water from the visited farm go? (Specify % of the total amount (total =100%)) (%) 1. Canal (%) 2. River (%) 3. Estuary (%) 4. Sea (%) 5. others: specify:______________________________
B18	Where does the sediment from the visited farm go? (Specify % of the total amount (total =100%)) (%) 1. Canal (%) 2. River (%) 3. Estuary (%) 4. Sea (%) 5. Dyke consolidation (%) 7. Fertiliser (%) 8. Others, specify: ____
B19	From B17, if you do not use the sediment for dyke consolidation, **why and what** material/method do you use for the dyke consolidation? Why? ____ What do you use?____
B20	Do you plant trees or vegetation on your dyke? ( ) 0. No ( )1.Yes If yes what tree/plant_______________ and for what? Dyke stabilization/wood/income/Other:

	____
B21	Can and do you drain your culture pond? ( ) 1. Cannot drain ( ) 2. Can drain shallow area but not ditch ( )0. No ( ) yes; Do you? ( ) 0. no ( ) 1. Yes ( ) 3. Can completly drain; Do you? ( )0. No ( ) yes; Do you? ( ) 0. no ( ) 1. Yes ( ) 4. Can and do completely drain and dry pond ( )0. No ( ) yes; Do you? ( ) 0. no ( ) 1. Yes. If yes how many times per year do you drain your pond? _______ Amount Before you start to dry your pond how deep was the sludge? (cm)________________ For how many days do you dry your pond each time you dry it? _________________days

PART C: FARM PRODUCTION INFORMATION (PER FARM)

Dry season for shrimp only: Month _____to _______(Total = ______ months)
Wet season for shrimp OR rice season for shrimp+ rice: Month ___ to __(Total = __ months)

POND PREPARATION including sediment removable (for all productions)			
C1	Pond preparation (which months?)		
C2	Sediment removable cost (VND/season)		
C3	Lime amount (kg/season)		
C4	Lime cost (VND/kg)		
C5	Total cost of other chemical (VND/season) (specify chemical: e.g., Formalin, chloride ___________________________________)		
C6	Organic fertilizer type ________________ amount (kg/season)		
C7	Organic fertilizer cost (VND/kg)		
C8	Inorganic fertilizer type _______________ amount (kg/season)		
C9	Inorganic fertilizer cost (VND/kg)		
C10	Hired labor amount (days)		
C11	Hired labor cost (VND per day)		
C12	Type of fuel:_____________________ Fuel amount (Liter/season)?		
C13	Fuel cost (VND per liter)		
C14	Dike/canal repairing (VND/year)		
C15	Sluice gate repairing (VND/year)		

C16	Other costs specify: __________________ (VND per season)		
CULTURE PERIOD (for all productions)			
C17	Feed amount (kg/season) (If feed by homemade, go to Annex 1)	Commercial (% protein): ___________ Homemade: _____________	Commercial (% protein): ___________ Homemade: _____________
C18	Feed cost (VND/kg)	Commercial: _____________ Homemade: _____________	Commercial: _____________ Homemade: _____________
C19	Drug cost, e.g., probiotic, anti-biotic specify:______________________________		
C20	Type of fuel:_____________________ Fuel amount (Liter/season)?		
C21	Fuel cost (VND per liter)		
C22	Total electricity cost (VND/season)		
C23	Hired labor amount (days)		
C24	Hired labor cost (VND per day)		
C25	Others: specify:________________________		
SHRIMP			
C26	Stocking months? (Specify months and stocking times for each month e.g., Jan (2 times)		
C27	Highest stock amount (PL/month)? And which month?		
C28	Average stock amount (PL/month)		
C29	Stock size/age range (PL size)		
C30	Seed cost (VND/PL)		
C31	Harvest month (specify months and harvest times for each month e.g., Jan (2 times)		
C32	Highest harvest amount (kg/month)? And which month?		
C33	Average harvest amount (kg/month)		
C34	Harvest price and proportion (%) of each		

	size			
	C34.1	Small:______________ pcs/kg	___VND/kg (%)	___VND/kg (%)
	C34.2	Medium:____________ pcs/kg	___VND/kg (%)	___VND/kg (%)
	C34.3	Large: _____________ pcs/kg	___VND/kg (%)	___VND/kg (%)
C35	Total income from shrimp harvest (VND/season)			
C36	Where do you sell the shrimp (% of crop) (Total = 100%)		(%) 1. Local market (%) 2. Middlemen (%) 3. Others, specify:________________________	
C37	What are the main causes of shrimp losses and how much loss in VND? (1=major lost)		1. _____________________________________ 2. _____________________________________ 3. _____________________________________ 4. _____________________________________	

		Dry season for shrimp only	Wet season for shrimp OR rice season for shrimp+ rice
RICE			
C38	Start planting (specify months?)		
C38	Total rice seeds (VND per season)		
C39	Other cost for rice: specify:______________		
C40	Harvest month (specify months?)		
C41	Total harvest amount (kg/ season)		
C42	Rice price (VND/kg)		
C43	Total income from rice (VND/season)		
FISH			
C44	Stocking months?		
C45	Average stock amount (fry/month)		
C46	Stock size/age range (cm)		
C47	Fry cost (VND/fry)		
C48	Other cost for fish: specify:______________		
C49	Harvest month (specify months?)		
C50	Total harvest amount (kg/ season)		

C51	Average fish price (VND/kg)		
C52	Average fish size (fish/kg)		
C53	Total income from fish (VND/season)		
CRAB			
C54	Stocking months?		
C55	Average stock amount (crabs/month)		
C56	Stock size/age range (unit?)		
C57	Crab seed cost (VND/crab)		
C58	Other cost for crab: specify:_____________		
C59	Harvest month (specify months?)		
C60	Total harvest amount (kg/ season)		
C61	Average crab price (VND/kg)		
C62	Average crab size (crabs/kg)		
C63	Total income from crab (VND/season)		
OTHER COSTS			
C64	Land tax/fee (VND per year)		
C65	Land lease (VND per year)		
C66	Do you have a loan and how much is the current amount (related to shrimp culture)		
C67	Loan interest (rate ____%)(related to shrimp culture) (VND per year)		
C68	Type of loan (Commercial Bank, Cooperative, Micro Finance Institution, Private Lending Institution, Other specify)		
C69	Others costs (VND/year): specify:____________________________		

PART D: CLIMATE CHANGE PERCEPTION

Use these tables for answer part D1 CONSEQUENCE AND ADAPTATION FRAMEWORK

Likelihood Scales

Rating	Liklihood
5 = Almost Certain	Could occur several times per year
4 = Likely	May arise about once per year
3 = Possible	May arise once in ten years
2 = Unlikely	May arise once in 10 years to 25 years
1 = Rare	Unlikely to occur during the next 25 years

Consequence Scales

Rating	Economic consequence
5 = Exemeley positive	Extreme increase in profitability
4 = Major	Business thrives
3 = Moderate positive	Significant general increase in economic performance relative to without climate change
2 = Minor positive	Individually significant but isolated areas of reduction in economic performance relative to without climate change
1 = insignificant positive	Minor increase in profitability relative to without climate change
0 = No consequence	No positive or negative impacts
-1 = Insignificant negative	Minor shortfall in profitability relative to without climate change
-2 = Minor negative	Individually significant but isolated areas of reduction in economic performance relative to without climate change
-3 = Moderate negative	Significant general reduction in economic performance relative to to without climate change
-4 = Major negative	Business are unable to thrive
-5 = Catastrophic	Business failure

positive implications please also explain in table D1. (for example: new species can be cultured, more income from farming or byproducts (fertiliser), more areas available for culture, pumping cost reduced etc...)

PART D1. CONSEQUENCE AND ADAPTATION

Climate change Explain what change (i.e. Irregular season: rain in dry season)	Observed in your area (yes or no)	If there was impact/consequence (positive or negative) on your farm, please answer Likelihood & Consequence questions below, for RATING, please rate by using tables above				Adaptation		
		Likelihood	Consequence					
		Rating (1-5)	Rating (-5 to +5)	Production gain/loss or farm improve/ damage?*	Economic gain or loss (PhP)	Measures used **	Cost of measures (PhP)	Level of success (0 not success, 5 problem solved)
D1.1 Irregular season: ____________________								
D1.2 Temperature rapid change: _____________								
D1.3 Temperature (high): _______________								
D1.4 Temperature (low): ____________________								
D1.5 Typhoon/storm: ____________________								
D1.6 Heavy rain: ____________________								
D1.7 Floods from rain: ____________________								
D1.8 Drought: ____________________								
D1.9 Water salinity increase: _____________								
D1.10 Water salinity decrease: _____________								

Climate change Explain what change (i.e. Irregular season: rain in dry season)	Observed in your area (yes or no)	If there was impact/consequence (positive or negative) on your farm, please answer Likelihood & Consequence questions below, for RATING, please rate by using tables above				Adaptation		
		Likelihood	Consequence					
		Rating (1-5)	Rating (-5 to +5)	Production gain/loss or farm improve/ damage?*	Economic gain or loss (PhP)	Measures used **	Cost of measures (PhP)	Level of success (0 not success, 5 problem solved)
D1.11 Tidal surge/flood (sea /river/canal level rise) If yes by how much change +/- _____cm Tidal surge no. times _____ & years observed: ___________________								
D1.12 Other: ____________________								
D1.13 Other: ____________________								
D1.14 Other: ____________________								
D1.15 Other: ____________________								

*for **positive implications** please also explain in table D1. (for example: new species can be cultured, more income from farming or byproducts (fertiliser), more areas available for culture, pumping cost reduced etc...)

****examples of adaptive measures**: Changed farming practices (feeding practices, adjust harvesting, post-harvesting and distribution strategies, adjust stocking densities, introduced new species), change farm infrastructure (increase dyke height, deeper ponds, shade pond), Shifted to other occupations, Got help (government, NGO, family, others), others, specify_______

PART D2: ADAPTABILITY

<table>
<tr><td>D2.1</td><td colspan="3">From Part E1 what is the most difficult to overcome the losses due to climate changes and why?
What?______________________________
Why? ______________________________</td></tr>
<tr><td>D2.2</td><td colspan="3">From Part E1, what climate changes become stronger and/ or more frequent and how?
What? ______________________________
How? ______________________________</td></tr>
<tr><td>D2.3</td><td colspan="3">From Part E1, what climate changes become weaker and/ or less frequent and how?
What? ______________________________
How? ______________________________</td></tr>
<tr><td rowspan="4">D2.4</td><td colspan="3">Please RANK who helped you most when you had serious losses on your farm due to any climate changes that you listed in Part E1 or other reasons in the last 3 years</td></tr>
<tr><td>_____ 1. Government agencies</td><td colspan="2">___ 2. Village authorities’</td></tr>
<tr><td>_____ 3. Friends and family</td><td colspan="2">___ 4. Own sources (themselves)</td></tr>
<tr><td>_____ 5. Private agencies</td><td colspan="2">___ 6. Others, specify:_______________</td></tr>
<tr><td rowspan="4">D2.5</td><td colspan="3">Please RANK the following support from the government /agencies in last 3 years related to shrimp farming that you received</td></tr>
<tr><td>_____ 1. Material support (post larvae, feed, equipment)</td><td colspan="2">___ 2. Financial support (grants, subsidies, loans)</td></tr>
<tr><td>_____ 3. Technical support</td><td colspan="2">___ 4. Training (skills development)</td></tr>
<tr><td colspan="3">_____ 5. Others, specify:</td></tr>
<tr><td>D2.6</td><td colspan="3">What do you think are going to be the most important impacts due to climate change in the next 5-10 years
1:.______________________ 2.______________________
3. ______________________ 4.______________________</td></tr>
<tr><td rowspan="7">D2.7</td><td colspan="3">Are you planning to use new measures in next few years in farming / due to the climate changes mentioned in Part D1 (specify what measure for what climate change?)</td></tr>
<tr><td>New measures</td><td>For what climate change?</td><td>Do you think that these will be sufficient to cope with the change (yes or no and why?)</td></tr>
<tr><td>( ) 0. No changes</td><td></td><td></td></tr>
<tr><td>( ) 1. Changing farming practices</td><td></td><td></td></tr>
<tr><td>( ) 2. Farming new species</td><td></td><td></td></tr>
<tr><td>( ) 3. Bunds/dyke, other structures</td><td></td><td></td></tr>
<tr><td>( ) 4. Other:</td><td></td><td></td></tr>
<tr><td></td><td>( ) 4. Other:</td><td></td><td></td></tr>
</table>

<table>
<tr><td></td><td colspan="5">( ) 4. Other:</td></tr>
<tr><td>D2.8</td><td colspan="5">Have you attended any skills training related to shrimp farming or climate change in 2008/2009?
( ) 0. No ( ) 1. Yes, specify:</td></tr>
<tr><td rowspan="5">D2.9</td><td colspan="5">If YES in E2.8, please answer E2.9</td></tr>
<tr><td>Type of training</td><td>Who organised?</td><td>Effective (Yes or No) and Why?</td><td>Helped to improve your farm (Yes or No) and why?</td><td>More such training should be conducted? (Yes or No) and why?</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">D2.10</td><td colspan="5">Which agencies are most capable or influential to provide support to farmers (rank 1 to 4) (Dept of Fisheries, Provincial govt. Communes, University, Research Institutes, Farmers agencies/ groups) and why?</td></tr>
<tr><td>1
Why?</td><td>2
Why?</td><td>3
Why?</td><td colspan="2">4
Why?</td></tr>
<tr><td rowspan="6">D2.11</td><td colspan="5">For each measure, do you think that it would be effective to overcome climate change impacts or losses? If yes then rank how effective you think they will be?</td></tr>
<tr><td colspan="3">Measures</td><td>Effective (yes or no)</td><td>If yes, ranking Effectiveness</td></tr>
<tr><td colspan="3">Improve technical & information support (training or awareness)</td><td></td><td></td></tr>
<tr><td colspan="3">Improve financial support /improve credit access, loan waivers, insurance, relief</td><td></td><td></td></tr>
<tr><td colspan="3">Increase level of farmer’s participation in climate change management</td><td></td><td></td></tr>
<tr><td colspan="3">Others, specify:</td><td></td><td></td></tr>
<tr><td>D2.15</td><td colspan="5">What is the biggest problem/challenge in running your farm, NOW? Choose one
( ) 1. Weather related, specify: ________________________________
( ) 2. Non-weather related, specify: ________________________________</td></tr>
<tr><td>D2.16</td><td colspan="5">What will be your biggest problem in running your farm in FUTURE? Choose one
( ) 1. Weather related, specify: ________________________________</td></tr>
</table>

	( ) 2. Non-weather related, specify: ____
D2.17	How long do you think that you will be still farming in the future? __________years or indefinitely. Why____

PART E: CLIMATE CHANGE MITIGATION

E1	What proportion of fuel can you reduce without a reduction in production or profitability? (%)
E2	What is the impact on your production (in kg) and profitability if you had to reduce your fuel consumption by 50% (estimate)? Product (i.e. shrimp, rice etc…): ___________ reduction in harvest _________ kg reduction in income: _____________VND
E3	What proportion of electricity can you reduce without a reduction in production or profitability? (%)
E4	What is the impact on your production (in kg) and profitability if you had to reduce your electricity consumption by 50% (estimate)? Product (i.e. shrimp, rice etc…): ___________ reduction___________ kg ______VND
E5	Are you using a windmill or other device (specify _______________) that does not use fuel or electricity to supply some of your pumping and or electricity needs? If not could you 1. Yes ( ) 2. No ( ). If you do or could what percentage could you supply using this alternative method? (%)
E6	Can you use bio-diesel instead of regular fuel? ( )0. No ( )1. Yes
E7	If you grow rice, do you practice burning the rice stubble after harvesting? ( )1. Yes ( )0. No, if not why ____

ANNEX 1: HOMEMADE FEED INFORMATION

1	Do you make homemade feed by yourself?	( ) 0. no ( ) 1. yes, what are % of the main ingredients? (answer below)	
2	Home made feed Ingredients	Percentage of total weight	Price (VND/kg)
3	What energy do you use for making homemade feed (electricity, wood etc.)?		