Vulnerability and adaptation to climate change for catfish farmers in the Mekong Delta

Case study report

Executive summary

Striped catfish farming is considered as quite a highly productive system (i.e. 350 – 400 tons of fish per ha.) in the lower Mekong river in Vietnam. Although the catfish industry has succeeded in recent years in the Mekong Delta, it faces several risks and challenges, especially from diseases, overexploitation of the environment, fluctuating price, higher quality requirement of the product, and climate changes, including salt water intrusion. The different production zones were found to be different in terms of their climate change impacts, productivity, culture system and socio-economic characteristics.

Catfish farmer's perception was different between different zones and specific climate change impacts. Some recent extreme weather and climate changes in temperature, precipitation, irregular weather and salt water intrusion were observed by catfish farmers in the Mekong Delta.

Overall, stakeholders perceived climate change as a threat to aquaculture in general and catfish farming in particular. Though farmers have started to adapt to the extreme weather events, their socio-economic context makes them vulnerable to climate variability. Stakeholder's priority was to improve the adaptive capacity through strengthening the current culture systems, producing good quality fry, funding support in the event of losses, training and supporting small scale farmers with necessary resources.

Policy makers need to provide access for credit and crop insurance to small scale cat fish farmers, strengthen co-ordination and cooperation between stakeholders and increase research funding to address climate change impacts assessment and adaptation. There is also a need to set up standardized environmental monitoring and weather forecasting systems and design and implement training and capacity building courses on climate change impacts.

Scientists and technology research institutions should research and develop fry and fingerling free of disease seed, disease diagnosis and treatment, vaccines against the major diseases, as well as improving quality of fingerlings. In addition, research to select salt and higher environmental change tolerance catfish strain that needs to be implemented by University and Research Institutes. They should provide training on using appropriate chemicals and drugs.

Adaptation measures for farmers included changes in management practices, producing and using good quality seed, developing new/improved culture systems/species, improved infrastructure, livelihood diversification, training and awareness workshops, financial support, and zoning and timing for culture area. In addition, improving adaptive capacity, developing early warning broadcast systems for RLS, flood & supporting small scale farmers with necessary resources were also recommended.

A long-term strategy for catfish production is recommended that salt tolerant seed production need to be researched to produce salt tolerant fingerling of catfish for sensitive area with saline water intrusion. In addition, hydraulic modeling should be applied for water flow prediction in the lower Mekong river, Vietnam.

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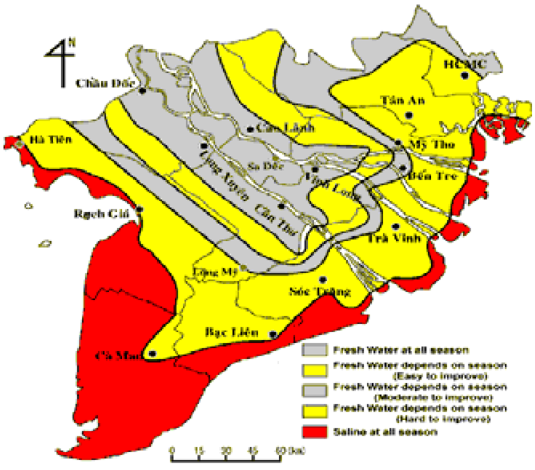


Fig. Status of saline intrusion in Mekong Delta

Catfish (*Pangasianodon hypophthalamus*) has been evaluated as a key species for export in Vietnam. Commercial catfish production started with *Pangasius bucourti* (Basa) cage culture in the 1960s in the Mekong Delta, then reached the peak of production in 1994. The peak period of catfish production was in 1996, when seed production technology of *Pangasianodon hypophthalamus* (stripped) catfish (locally known as Tra catfish in Vietnam) was developed (Trong and Oanh, 2009). In 10 years (2001 – 2010), Catfish culture area and production increased dramatically, almost 5 fold in culture area, i.e. 6,000 ha and by 36 times in production (from 37,500 tons to 1.35 million tons), total exported Pangasius fillets increased 40 times (from 17,000 tons to 660,000 tons), export revenue increased 35 times, i.e. from US$ 40 million to US$ 1,427 million (Nguyen Huu Dung, 2011). In 2011, total Pangasius culture area and production was estimated around 5,430 ha and 1,195,344 tons in the Mekong Delta (Directorate of Fisheries, 2012). Total culture area and production of catfish has been planned for 2010, 2015 and 2020; and targeted for 9,000 ha and 1,250,000 tons, 11,000 ha and 1,800,000 tons, and 13,000 ha and 2,000,000 tons, respectively (MARD, 2009). Although the catfish industry has succeeded in recent years in the Mekong Delta, it faces several risks and challenges, especially from diseases, overexploitation of the environment, fluctuating price, higher quality requirement of the product, and climate changes, including salt water intrusion.

Dasgupta et. al. (2007) suggests that Vietnam is one of world's top five most vulnerable countries to sea level rise and the most vulnerable to climate change impacts in South East Asia. Societies will be impacted in many ways by climate change and one of the primary ways will be food production and the associated environment (IPCC, 2007). According to De Silva and Soto (2009), major factors of climate change that may impact aquaculture are temperature and sea level rise, monsoon rain patterns and extreme events. Dang et al. (2010) reported that rice production was more sensitive to weather variability than aquaculture, and shrimp production is more directly sensitive than Pangasius catfish culture.

However, the Delta region is highly vulnerable to various problems, especially climate changes and extreme weather events. Most serious problems are from changing weather patterns, early rains, higher temperatures, floods, typhoons and salt water intrusion due to sea level rise. At the same it is dominated by small scale farmers who are vulnerable to changes in the climate and extreme weather events.

1.1 Goal

To assess the impacts of climate change on small scale aquaculture (environmental, socio-economic, productivity and institutional) in catfish case study in the Mekong Delta.

1.2 Specific objectives

- To map the farmers perceptions and attitudes towards climate change impacts and their adaptive capacities to cope with these impacts;
- To assess the potential impact of the culture systems;
- To analyse potential adaptation measures for catfish farming systems;
- To recommend on cost effective measures that can be implemented by farmers and technical and government support for the farmers

2. Review on technical and economic aspects of Striped catfish farm

2.1 Striped catfish production in ponds

The level of experience in catfish farming was high with an average of 5 years, and most farmers had attended training courses on catfish culture technique, especially in the up-stream zone. Most farmers were from secondary and high school education level in up and mid-stream zones, but less educated in the down-stream zone (Figure 1). More than 60% of farmers had their own land for catfish farming (Table 1).

Table 1: Some general catfish farmer's information in the study area

	Upstream (n=53)	**Midstream (n=107)**	**Downstream (n=30)**
Age	48.1 ± 9	46.8 ± 11.5	46.8 ± 11.5
Experience (years)	5.0 ± 2.6	4.6 ± 2.6	4.6 ± 2.6
% of household attended training course	86.8	43.7	63.4
Land ownership (%)	62.3	68.3	63.6

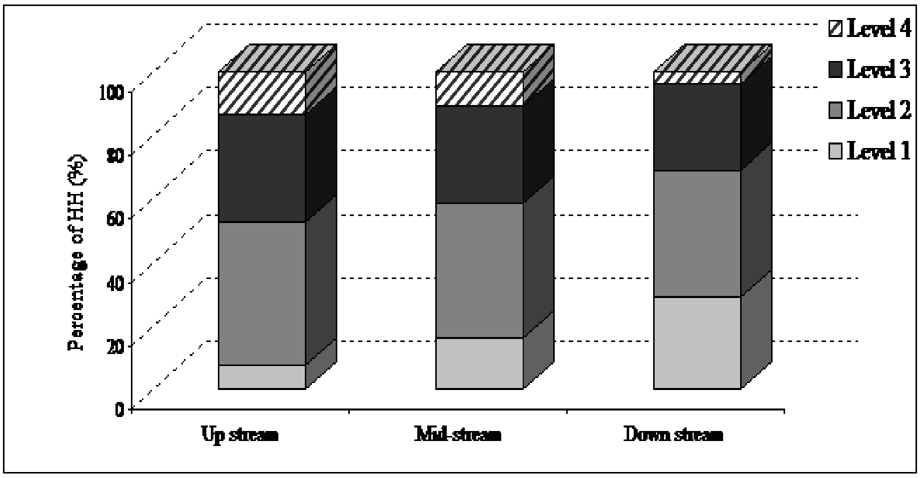


Figure 1. Catfish farmer's education level in the study area

The catfish culture system is typically considered as small scale farm with 1-2 farm(s) per household and 1-3 ponds within a farm. Average water area of pond is around 0.4 ha/pond. Pond area, water depth and stocking density of catfish farms in down stream zone were smaller and shallower and lower density than that in up and mid-stream zones (Table 2). Fingerling stocking density was highest in mid-stream zone (54.7 ind./m^2). However, there was no significant difference among these zones. Fingerling stocking size ranged from 1.5-2 cm in body depth and harvested weight ranged from 0.8-1 kg/fish after a 7-8 months culture period. Commercial pellet feed was used for catfish farming in up (91.3%) and down stream zones (100%), especially. Both commercial pellet and home-made feeds were used in ratio of 52.6% and 47.4%, respectively in the mid-stream zone (Table 2). Feed conversion rate (FCR) in up and down stream zones was lower (1.6-1.7) than that in the mid-stream zone (2.3). Fish harvest yield in the down stream was lower (293 tons/ha) than that in up (359 tons/ha) and mid-stream (339 tons/ha) zones. Average survival rate of fish in the mid-stream zone was a little lower (72.1%) and more varied than that in up and down stream zones (Table 2). According to Nguyen (2008), stocking density and harvest yield of catfish pond culture ranged around 30-40 ind./m^2 and 250-300 tons/ha, respectively, with FCR was ranged from 2.8 to 3.0 for home-made feed and 1.5 to 1.8 for commercial pellet feed in the Mekong Delta. A recent study reported that stocking density and harvest yield of striped catfish cultured in pond in light salt water intrusion area in dry season, i.e. down stream zone of low Mekong river in Vietnam were 30.5 ind./m^2 and 208.7 tons/ha, respectively lower than that in whole year round freshwater area, i.e. 54.7 ind./m^2 and 416.1 tons/ha, respectively (Lam et al., 2010).

Table 2: Catfish production in the study areas

	Up-stream	**Mid-stream**	**Down-stream**
No. own farms	1.5 ± 0.7	1.4 ± 0.8	1.4 ± 0.7
No. pond in interviewed farm	2.0 ± 1.0	2.2 ± 1.4	2.1 ± 1.4
Total water area of the farm (ha)	0.8 ± 0.6	0.8 ± 0.6	0.6 ± 0.6
Pond water area (ha)	0.4 ± 0.2	0.4 ± 0.2	0.3 ± 0.2
Pond depth (m)	4.6 ± 0.9	4.7 ± 0.7	4.0 ± 0.8
Water depth (m)	3.8^{a} ± 0.8	4.0^{a} ± 0.6	3.2^{a} ± 0.7
Stocking density (ind./m^2)	40.9^{a} ± 12.0	54.7^{a} ± 24.0	39.1^{a} ± 19.6
Fingerling size (cm in depth)	1.8 ± 0.3	1.8 ± 0.6	1.5 ± 0.2
Used commercial pellet feed (%)	91.3	52.6	100
FCR	1.7^{a} ± 0.2	2.3^{a} ± 0.8	1.6^{a} ± 0.2
Survival rate (%)	74.6^{a} ± 8.8	72.1^{a} ± 18.1	75.5^{a} ± 14.0
Yield (tons/ha)	359^{a} ± 221	339^{a} ± 176	293^{a} ± 264
Average harvest size (kg/fish)	1.0 ± 0.2	1.0 ± 0.2	1.0 ± 0.1

The values in the same row with the same letter are not significant difference (p>0.05)

2.2 Economic aspects of catfish production

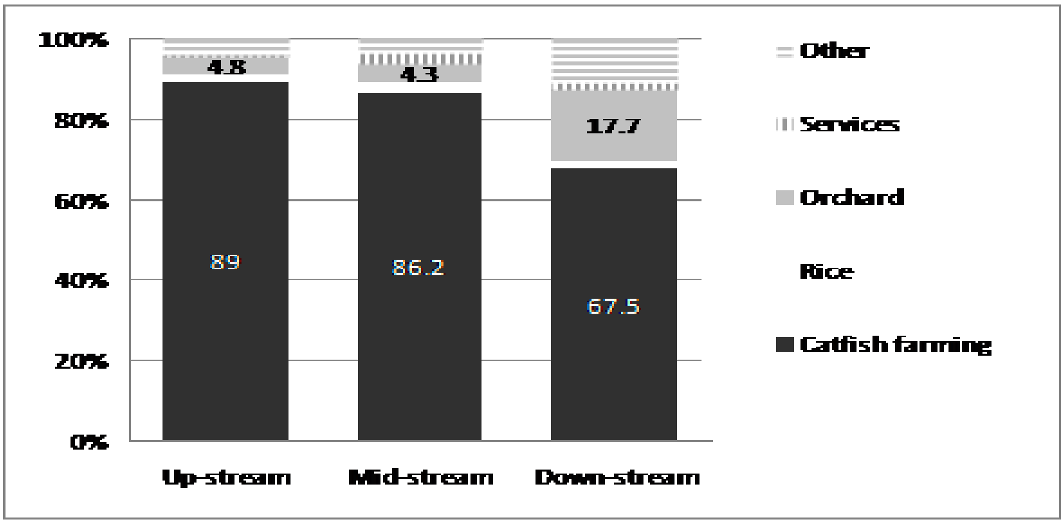


Figure 2. Percentages of catfish household's income sources

The income from striped catfish culture was considered as a major household income for catfish farmers in the study area. Percentage of the household's income from catfish farming in the down stream zone was 67.5%, lower than that of catfish farmers in up and mid stream zones, but the income from growing fruit trees (orchards) in the downstream was significantly higher (18%) than that in up and mid-stream zones (Figure 2). In catfish production , major cost was on feed (86-88%), followed by fingerlings (5.0-5.5%) respectively (Figure 3).

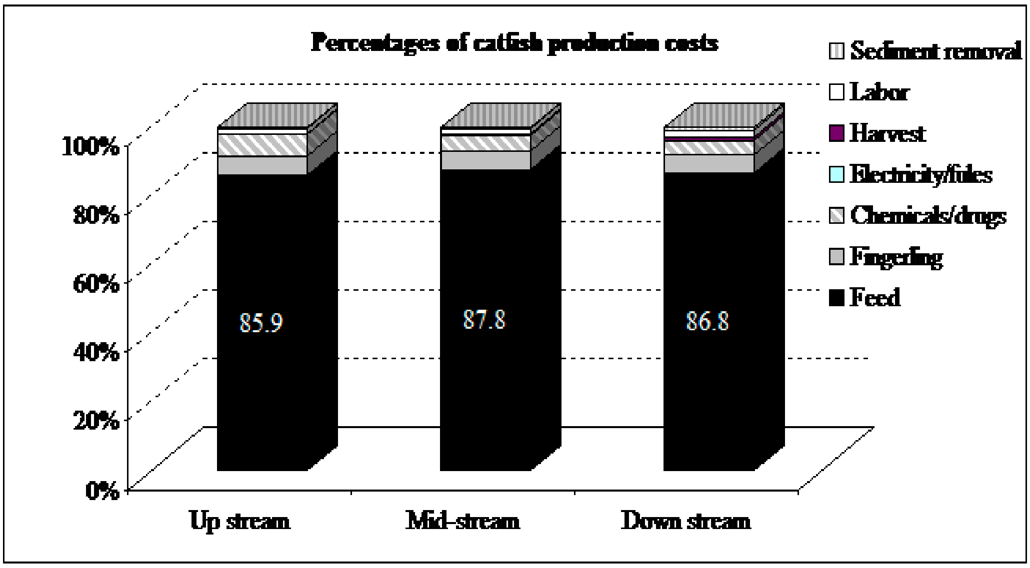


Figure 3. Ratio of catfish production costs in the study area

A previous study reported that the feed and fingerling costs of striped catfish production were 80.5% and 7.5% in the up and middle stream zones and 62.5% and 6.4% in the down stream zone (Le, 2008). Another study also reported that the feed and fingerling costs of striped catfish farming were 80.8% and 2.0% in the up and middle stream zones, respectively, and 78.3% and 1.3% in the down stream zone (Lam et al., 2010). According to our study, the cost investment of catfish farming, especially feed and fingerling costs have increased. This maybe a big concern for catfish farmers in the Mekong Delta in the future.

Total production cost of catfish culture in the down stream zone was almost half as compared to up and mid-stream zones, especially with respect to feed and fingerling costs. Average cost per kilo of fish was around VND 15,000/kg of fish. Total revenue of catfish production was double in up and mid-stream zones than that in the down stream zone, but profit was lower than in down stream zone (Table 3). One important reason for this is that feed expenditure, i.e. 100% of catfish farmers in the down stream zone used commercial pellet feed, meanwhile home made feed was used in combination with commercial feed in the up stream zone, and particularly the mid stream zone.

Table 3. Some main economic variables in striped catfish pond culture in up, mid and down stream zones

(Unit: VND million/ha/crop)

Economic items	Up-stream n=53	Mid-stream n=107	Down-stream n=30
Costs			
Feed(s)	4,455.5 ± 2,043.5	5,387.2 ± 3,389.8	2,654.2 ± 1,148.6
Fingerling	291.4 ± 172.6	327.7 ± 286.8	154.3 ± 81.7
Chemical/drugs	330.5 ± 280.1	278.5 ± 212.0	134.8 ± 84.4
Electricity/fuel	18.3 ± 31.3	10.8 ± 26.6	2.1 ± 2.6
Harvest	0.0	29.5 ± 29.2	25.6 ± 18.2
Labour	72.6 ± 49.9	75.1 ± 60.7	59.8 ± 30.7
Sediment removal	18.0 ± 11.1	27.2 ± 26.6	25.6 ± 18.2
Total cost	5,186.2 ± 2,588.5	6,136.0 ± 4,031.7	3,056.4 ± 1,384.5
Revenue	5,054.1 ± 1,782.8	5,882.1 ± 2,177.1	3,082.8 ± 1,282.4
Profit	-132.1 ± 805.7	-230.3 ± 1,854.6	27.8 ± 100.3
B/C	-0.98	-0.96	1.01
Gained profit (% HH)	26.0	20.0	17.0

3. Perception of climate change impacts and adaptation of catfish farming in the Mekong delta

3.1 Perceptions of climate changes and their impacts

A number of changes in typical climate that were identified as follows:

- Increasing changeable weather patterns
- Higher river and canal water level increase and more frequent floods
- Rainy season starting earlier
- Increasing salt water intrusion
- Increase in the number of hot days and longer hot season

- Increase in the number of cold days
- Increasing incidence of sudden heavy rain
- Increasing incidence of storms and typhoons

These changes provided impacts mainly to farm production. The participants described measures that they were already taking and potential solutions to be able to adapt to the changes. They described who could be responsible for undertaking the adaptation measures and the timescale required for successful implementation.

The climate changes described are based on the participants's perceptions and need to be checked against metrological records and the adaptation measures used and suggested are based on their ideas and there is a need to check the scientific basis for those measures.

3.2 Increasing changeable weather patterns

Participants were observing irregular and changeable weather patterns particularly in the level of sunshine and rain in the periods between the dry and rain seasons. These impacts led to the fish becoming stressed and losing appetite resulting in slower growth. Measures already taken by the farmers and suggested measures included:

- Improved feed nutrition to be able to improve growth rate such as adding Vitamin C and digestive probiotics to the diets.
- The use of lime on the slopes of the dikes and the liming of pond after draining. Developing a work plan for liming was suggested.
- Adding salt to the pond water to help stabilise water quality.

However they also need additional support as follows:

- Advice and help from Scientists and research institutions
- Advice from the fishery managers at District and provincial level
- Free seed from the Provincial Government hatcheries

These measures are able to be implemented in the medium term (3 to 5 years).

3.3 Higher river and canal water level increase and more frequent floods

The impacts of increased water levels that the farmers are experiencing include the following:

- Stronger water flows leading to dike erosion but also leading to improved fish quality as there is a higher rate of water exchange.
- Damage to pond facilities

- Change in water quality such as low pH and higher turbidity levels leading to increased disease outbreaks
- Loss of fish due to escapes
- Higher disease incidence generally
- Higher capital costs due to the need to repair and upgrade dikes (estimated cost at 20 million Dong/ha for a private company to undertake)

Measures already taken by the farmers and suggested measures included:

- Upgrading of the pond dikes
- Increasing the height and strengthening the sluice gates
- The construction and use of sedimentation ponds to improve water quality
- Addition of salt, Chlorine and Copper Sulphate to the pond water
- Addition of lime to the pond walls
- Improve fish feed nutrition with the addition of Vitamin C
- Reduce the cost of feed by including snail meal as an ingredient to the home made feed
- Plant trees on dikes to strengthen them

Participants are able to undertake some adaptive measures which are within their control but they will have to rely on additional external support as follows:

- Advice and help from Scientists and research institutions
- Need a University Research Centre specialising in Disease diagnosis and treatment
- Research and development by scientists on improved fish medication and fish vaccines
- Research and development by scientists on improved fish medication and fish vaccines
- Need hatcheries to supply fry and fingerlings free of disease
- Advice from the fishery managers at District and provincial level
- Advice and training from chemical and drug supply companies on appropriate chemicals to use
- Investment by the Department of Planning to improve the water supply and drainage infrastructure
- Investment by the Irrigation Department to improve the irrigation system

- Need an improved river level rise and flood forecast system by Department of natural Resources and Environment
- Need an improved early warning broadcast system by TV stations
- Need mass communication by Department of Communication and Education
- Need investment by Government to maintain, heighten and repair the main river and canal dikes (Department of Environment and Natural Resources, Department of Agriculture and Rural development, Institute of Irrigation at Provincial level)
- Need the establishment of more Environmental Police Units as has been established for Can Tho City.

3.4 Rainy season starting earlier

Participants are observing that the rainy season is starting early. The impacts of early rainy season that the farmers are experiencing include the following.

- Fish lose appetite leading to reduced growth rate
- Fish become stressed leading to up to 30% mortality
- Production costs are higher due adaptation measures that have to be taken.
- Measures already taken by the farmers and suggested measures included:
- Use of better feeds for example a quality feed costs 7,500 D/kg compared to normal cost of 7,000 Dong
- Improve the nutrition quality of the feed by adding Vitamin C
- Purchase better quality seed which have better growth rate and less disease
- Use probiotics in the pond to stabilise water quality
- Pump sediment from the pond after stocking fingerlings
- Pump sediment from pond regularly (at least 3 times) before harvesting
- Change the crop calendar to take into account the weather changes
- Share experiences and solutions between farmers

Most of these measures are able to be carried out by the farmers themselves and they are able to cope and adapt to this weather change. However they also need additional support as follows:

- Advice and help from Scientists and research institutions
- Advice from Chemical and drug companies
- Improve seed quality from Government and private hatcheries

3.5 Increasing salt water intrusion

Participants are observing increasing saline water intrusion into catfish culture areas. The impacts of increasing saline intrusion that the farmers are experiencing include the following:

- Loss of production area
- Lower productivity from the ponds
- Fish have lower appetite leading to slower growth.
- Increased incidence of disease
- Poorer flesh quality (lower white meat ratio)
- Poorer water quality for catfish

Measures already taken by the farmers and suggested measures included:

- Exchange water daily
- Use probiotics to improve fish health
- Use better quality feeds to improve growth rate
- Harvest earlier to avoid the higher salinity
- Change to a different species
- However the farmers also need additional support as follows:
- Advice and help from Scientists and research institutions
- Need for better aquaculture planning and aquaculture zoning by the Department of Agriculture and Rural Development
- Need a study on potential new salt tolerant species for culture
- Need to genetically select catfish for salt tolerance

3.6 Increase in the number of hot days and longer hot season

Increasing number of hot days, hotter days and a prolonged hot season were identified. The impacts of hotter weather that the farmers are experiencing include the following:

- Increased water temperature in the ponds leading to abnormal fish behaviour
- Increase water temperature in the ponds leading to increase in Bacterial and viral diseases
- Change in water quality particularly high Ammonia levels
- Decrease in fish growth rate

- Higher production costs due to the adaptation measures that they have to implement

Measures already taken and suggested measures included:

- Treating the water before pumping into the pond
- Exchange a greater amount of water each day but not more than 30% per day otherwise it stresses the fish
- Remove the sediment from the pond more frequently
- Use lime

Most of these measures are able to be carried out by the farmers themselves.

3.7 Increase in the number of cold days

Increasing number of cold days particularly from August was also addressed. The impacts of cold temperatures that the farmers are experiencing include the following:

- Changes in pond water quality
- Build up of toxic substances in the pond.
- Increase in bacterial disease outbreaks
- Increase in parasite problems
- Lower fingerling survival being reduced from 90% to 70% survival
- Reduced Food conversion rate by 0.1:1
- Increased operational costs due to increased expenditure on medication (Normally 300VND/kg which is increased to 500 to 1,000 VND/kg)

Measures already taken and suggested measures included:

- Increase water exchange in the ponds by pumping
- Siphon the bottom of the pond more frequently
- Improve the nutrition quality of the feed
- Use chemicals (probiotics) to absorb the toxic substances

Most of these measures are able to be carried out by the farmers themselves. However also needed is additional support as follows:

- Advice from commercial chemical and drug supply companies
- Need research to improve quality of fingerlings
- Need research to develop strain of fish with high environmental change tolerance

3.8 Increasing incidence of sudden heavy rain

Increasing periods of heavy rain and increasing frequency of sudden heavy rain were observed. The impacts of increased water levels that the farmers are experiencing include the following:

- Pond water temperature decreases rapidly.
- Increase in bacterial disease
- Increase in parasite problems
- Reduced fish appetite leading to slower growth rate
- Reduced flesh quality (more yellow flesh – market price of 13,200 VND/kg than white flesh market price 14,200 VND/kg)
- Increase in water pollution in supply water due to agricultural pesticide runoff
- Increased production cost due to increased chemical and medication used (additional 100 VND/kg)

Measures already taken and suggested measures included:

- Add vitamin C to the diet weekly
- Add probiotic to the pond water to stabilise water quality
- Use sorbitol
- Most of these measures are able to be carried out by the farmers themselves. However the also need additional support as follows:
- Develop and produce vaccines against the major diseases. This should be funded by the government and undertaken by RIA 2 but will be long term before results (probably 2015).

3.9 Increasing incidence of storms and typhoons

Typhoons typically occur in November in the Mekong River delta area. The impacts of increased number of storms that include the following:

- Destroy the irrigation water supply and discharge system
- Create high canal water levels
- Cause escape of fish from the ponds by escapes
- Reduced production.

Measures already taken and suggested measures included:

- Strengthen pond dikes

4. Stakeholder and Institutional 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 in the table below.

4.1 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 pangasius 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.

4.2 Institution importance

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

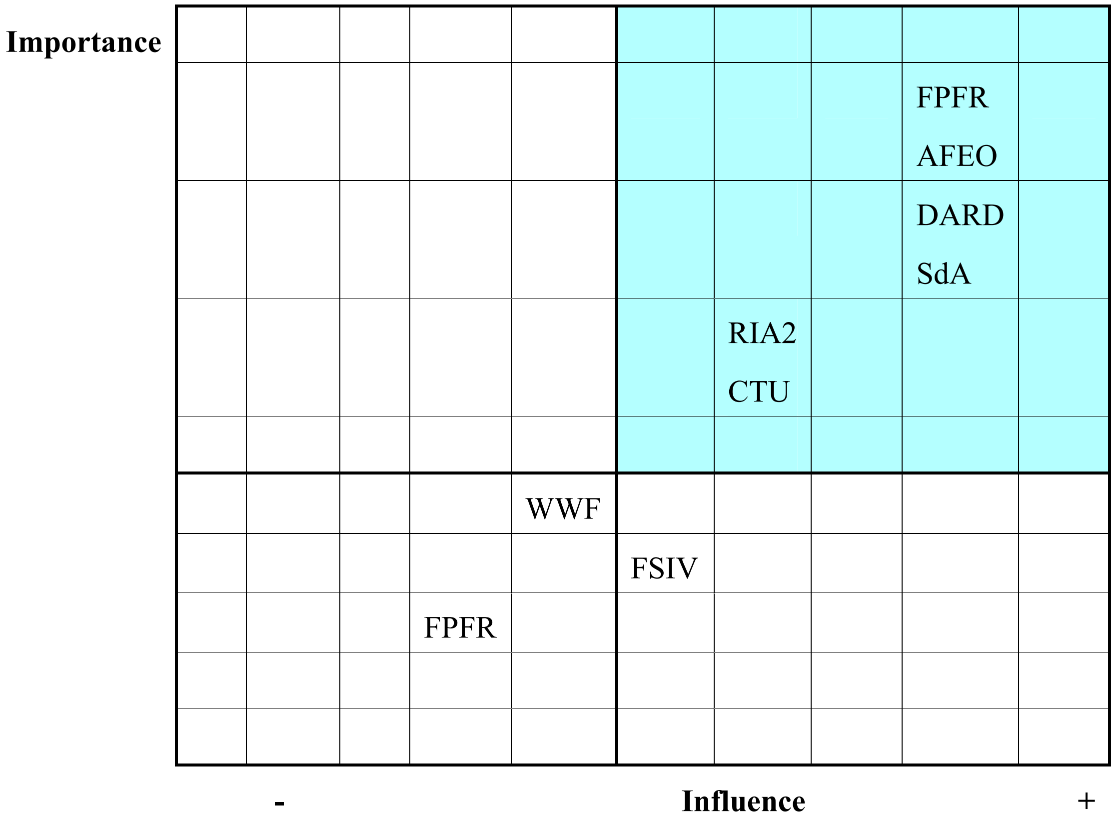
Table 4: Assessment of institution importance and influence

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 FisheriesExtensionCenter (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 5: 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 (6).

Table 6: 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

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.

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 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. The centres for monitoring environment and diseases play important roles in early warning outbreak diseases and environmental impacts.

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 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.

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 are a very useful tool for recognizing the climate change events and their impact, discussing problems and finding solutions.

4.3 Responsible agencies

In many cases, the adaptive measures could be undertaken by the farmers themselves. However there are issues outside their control where they believe they need assistance from:

- Government (Central, Provincial and District)
- Private commercial companies
- Universities and Research Institute assistance

4.4 Government (Central, Provincial and District)

- Advice from the fishery managers at District and provincial level
- Free seed from the Provincial Government hatcheries
- Need hatcheries to supply fry and fingerlings free of disease
- Improve seed quality from Government hatcheries

- Investment by the Department of Planning to improve the water supply and drainage infrastructure
- Investment by the Irrigation Department to improve the irrigation system
- Need an improved river level rise and flood forecast system by Department of natural Resources and Environment
- Need an improved early warning broadcast system by TV stations
- Need early warning mass communication by Department of Communication and Education
- Need investment by Government to maintain, heighten and repair the main river and canal dikes (Department of Environment and Natural Resources, Department of Agriculture and Rural development, Institute of Irrigation at Provincial level)
- Need the establishment of more Environmental Police Units as has been established for Can Tho City.
- Need for better aquaculture planning and aquaculture zoning by the Department of Agriculture and Rural Development

4.5 Private commercial companies

- Need hatcheries to supply fry and fingerlings free of disease
- Improve seed quality from private hatcheries
- Advice and training from chemical and drug supply companies on appropriate chemicals to use.

4.6 Universities and Research Institute assistance

- Advice and help from Scientists and research institutions
- Need a University Research Centre specialising in Disease diagnosis and treatment
- Research and development by scientists on improved fish medication and fish vaccines
- Need a study on potential new salt tolerant species for culture
- Need to genetically select catfish for salt tolerance
- Need research to improve quality of fingerlings
- Need research to develop strain of fish with high environmental change tolerance

- Develop and produce vaccines against the major diseases. This should be funded by the government and undertaken by RIA 2 but will be long term before results (probably 2015).

Table 7. Climate change impacts and agencies responsibility

Climate change issues	Impacts	Farmer level	Provincial level/Scientists	National level
Water level increase and flood	Water quality & quantity (salt water intrusion) Pond structure Diseases Loss income	Increase pond dykes Improve water quality	Advice crop calendar management (Department of Agriculture and Rural Development - DARD) Environmental monitoring (Department of Natural Resources & Environment-DONRE) Improve feed & seed quality (CTU/RIA2) Alternative species (salt tolerant species) (CTU/RIA2) Provide training course (DARD/CTU) Zoning for culture area (DARD) warning broadcast system (Department of communication and education)	Support budget Master plan
Irregular season	Water quality & quantity	Select better seed/feed quality	Advise technical & farm – management knowledge sharing (DARD/CTU)	Support budget

	Fish street & diseases Poor flesh quality Loss income	Improve water quality	Enhance the heath & resistance of fish (CTU/RIA2) Develop vaccines (CTU/RIA2) Research and advise closed system (CTU/RIA2) Environmental monitoring (DONRE)	
Hot season	Water quality & quantity Street & diseases Loss income	Increase water exchange Apply aeration system Select new strain on temp. tolerance Using floating aquatic plants	Advice crop calendar management (Department of Agriculture and Rural Development - DARD) Zoning for culture area (DARD) Environmental monitoring (DONRE)	Support budget Master plan

5. Future predicted climate change

5.1 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.

5.2 CSIRO model

The case study Provinces 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 4: Mekong River Basin

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

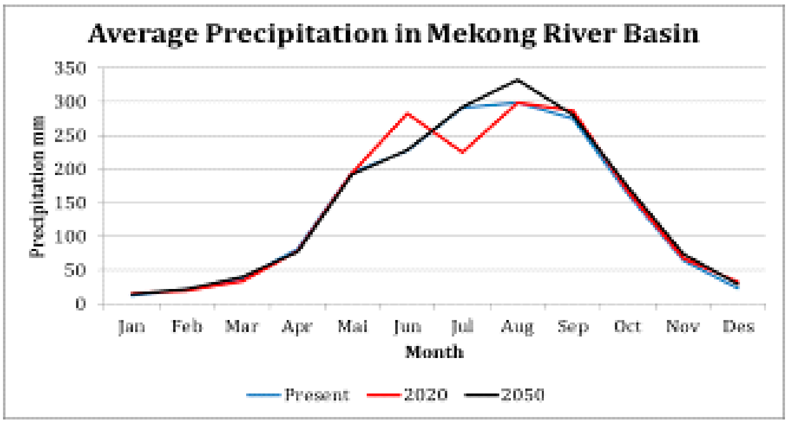


Figure 5: Predicted precipitation in the Mekong River Basin

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.

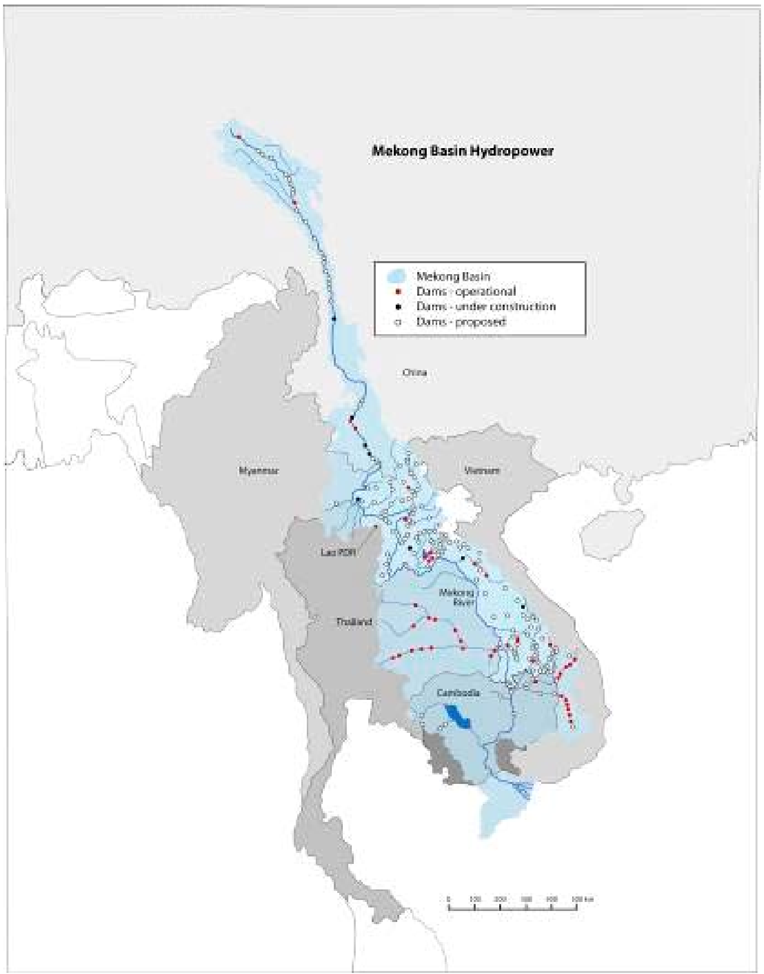


Figure 6: Constructed and planned dams along the Mekong River

Peak river flow may therefore be controlled by 2050 resulting in less flooding than predicted but with slight increase in the case study provinces.

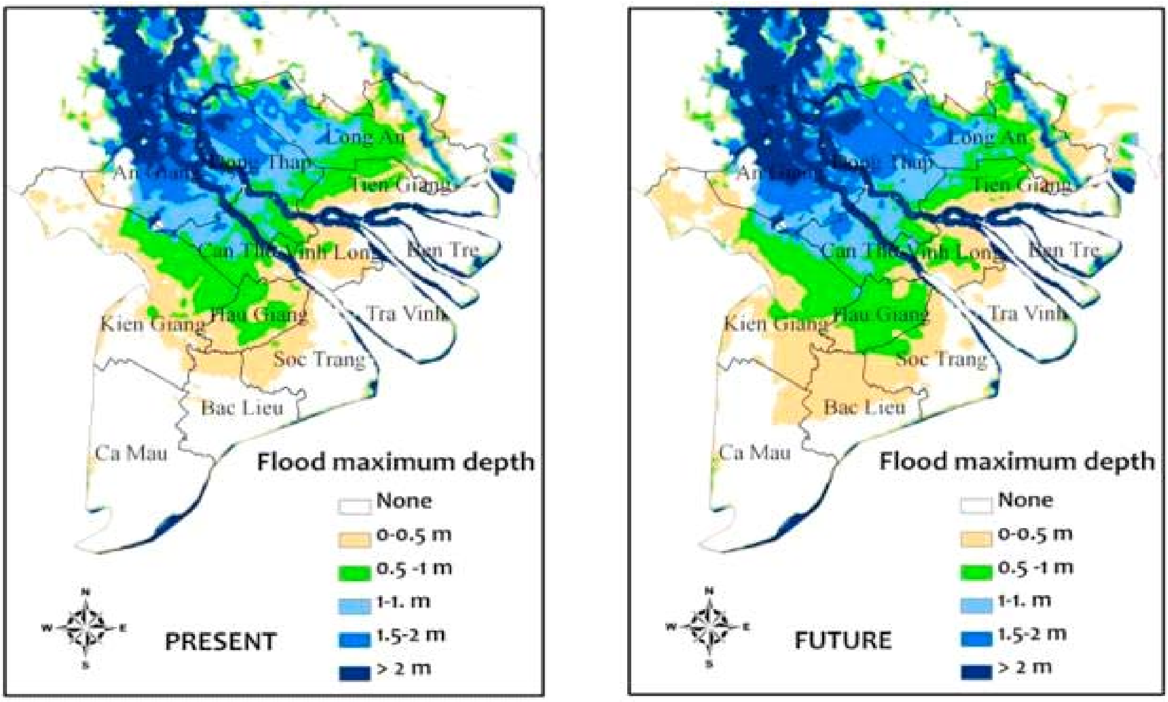


Figure 7: Predicted flood extent and severity

5.3 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).

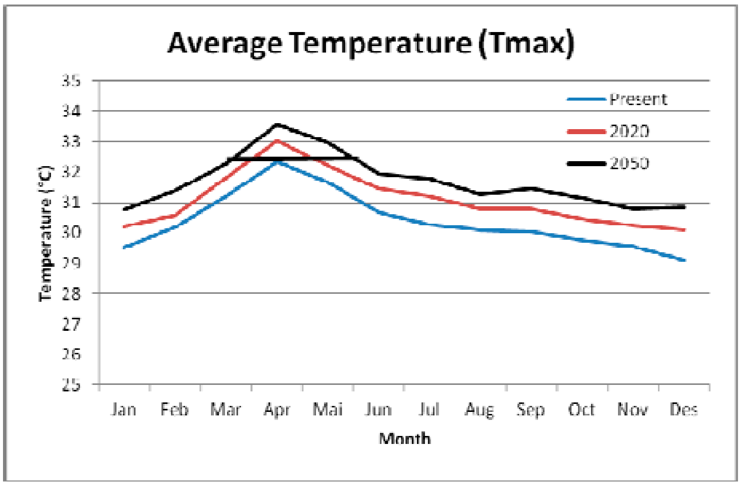


Figure 8: Average monthly maximum temperature at the Province level

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.

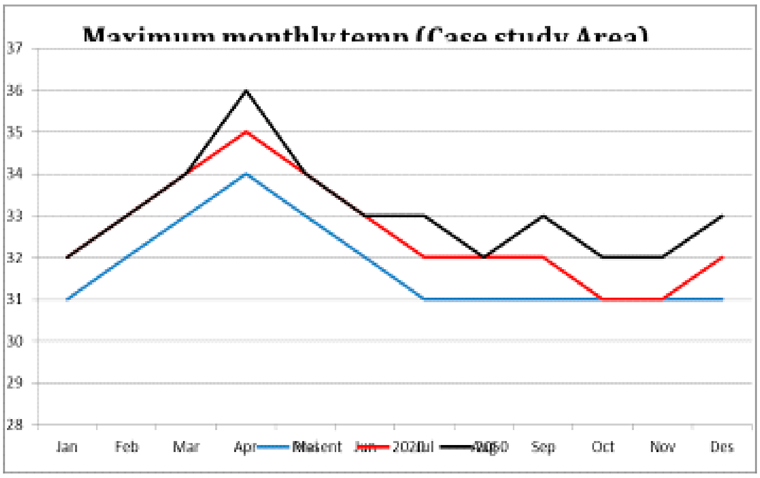


Figure 9: Predicted peak maximum monthly temperatures at Provincial level

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.

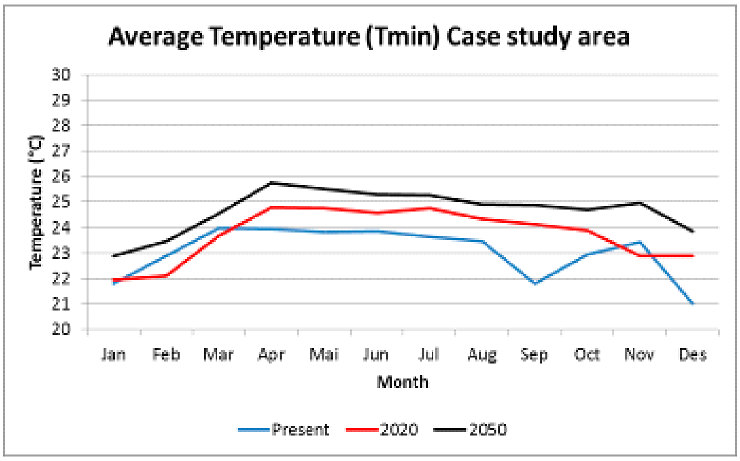


Figure 10: Minimum monthly average temperatures in the case study provinces

5.4 Precipitation

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

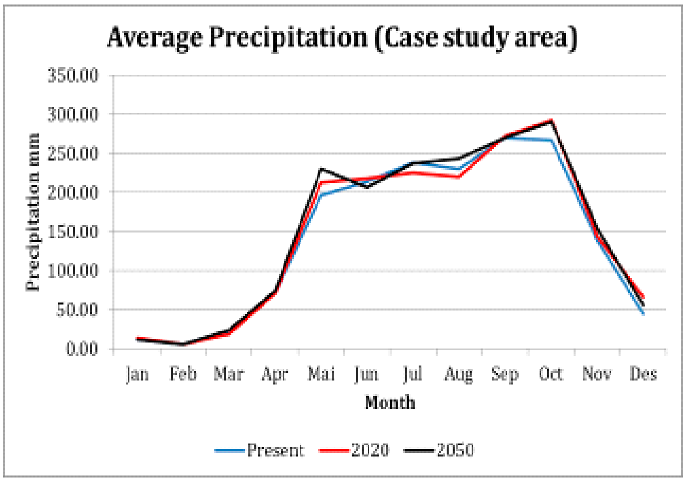


Figure 11: Predicted precipitation in the case study provinces

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.

5.5 Sea level rise

Sea level is predicted to rise with time.

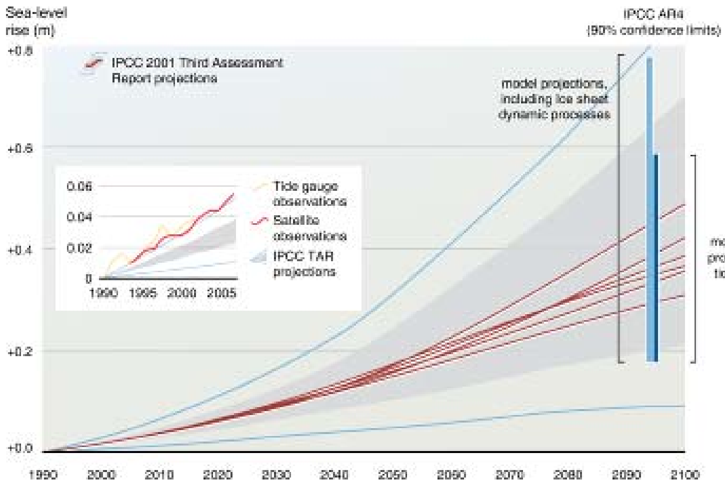


Figure 12: Predicted sea level rise

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.

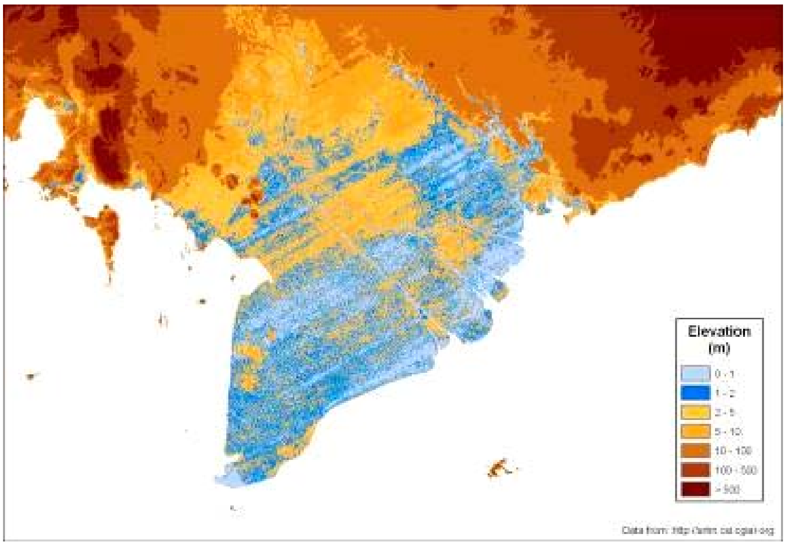


Figure 13: Elevation of the Mekong river delta above present sea level

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. Socio economic analysis

6.1 The main socio-economic characteristics of farmers

The surveyed farmers were from five provinces; Dong Thap, Vinh Long, Can Tho, Tra Vinh and Soc Trang. All of them belonged to the Kinh ethnic group. The average age of the interviewed farmers was 46 years (range 22 to 71 years), with more than two-thirds falling in the 30-60 years age group. Their experience in aquaculture ranged from 1 to 17 years with an average of 5.3, with 50 % had an experience of 5-10 years. In fact, catfish farming picked up in the region only in the last 7-10 years (Phuong and Donh 2009). Table 5 provides the distribution of age, occupation and experience in aquaculture province-wise.

Table 8. Socio-economic characteristics of the farmers surveyed

Province/ total		Age (years)				Main occupation		Number of years in aquaculture			
Province	Total (n)	< 30	30 - 45	45 - 60	>60	Fish farming	Others	< 5	5 -10	10 - 15	> 15
Dong	53	1.9	30.2	56.6	11.3	73.6	26.4	45.3	49.1	3.8	1.9

Thap											
Can Tho	82	12.2	39.0	39.0	9.8	89.0	11.0	34.1	51.2	12.2	2.4
Vinh Long	25	16.0	20.0	56.0	8.0	68.0	32.0	56.0	40.0	0.0	4.0
Soc Trang	15	6.7	33.3	53.3	6.7	66.7	33.3	53.3	46.7	0.0	0.0
Tra Vinh	15	0	46.7	40.0	13.3	60.0	40.0	40.0	60.0	0.0	0.0
Overall %		1.9	30.2	56.6	11.3	73.6	26.4	45.3	49.1	3.8	1.9

6.2 Education and Training

The majority of the farmers surveyed have an education up-to level 3 (school years 10 to 12). In all the provinces except Tra Vinh, about 42 to 48 % of the farmers have an education level 2 (school years 6 to 9). About 39 % of the farmers did not attend any training in aquaculture to date and the rest had attended training in aquaculture (between 1-4 times). In these trainings, farmers are provided information about extreme weather events and climate change and possible adaptation options to address such impacts. Of the 116 farmers who underwent training, 112 farmers stated that they benefited from the training, especially to update their knowledge on extreme weather events and related issues. About 121 farmers (64 % of the total) were of the opinion that skilled training would help them to improve catfish farming and more of such trainings should be conducted in the future.

6.3 Household size and earning members

The household size of sampled farmers ranged from 1 to 12, with an average of 5 members per household. The number of earning members ranged from 1 to 10, with an average of 3.5 persons per household. The percentage of earning members to household size was on average 67.7 %.

6.4 Awareness/ and perceptions of farmers to relevant climate change issues and perceived risks

Respondents had a wide range of views on climate change, extreme weather events and their occurrence and risks, ranging from being very negative to not being concerned at all. Some farmers were well informed about extreme weather and changes occurring in climate either though training workshops or through various media. Nearly 40 % of the farmers reported that they observed “many” climatic changes during the last 10 years, while 42% of the farmers expressed the change as “somewhat” and 19% of the farmers did not notice climate change events. Overall, a majority of farmers perceived a change in climate and more frequent extreme weather events in the recent years. Table 6 gives the frequency of farmer observations of the changes in weather and climate variability located in the different provinces surveyed.

A Chi-square test was used to test if farmer perceptions differed between provinces. The test indicated that the perceptions differed from one province to another (Chi-square value 79.9 and P< 0.01). Further, to determine the strength of association between these two variables, Cramer's V-statistic was computed and its value was 0.47 indicating a substantial association between farmer perceptions and province (0 indicates no association and 1 indicates complete association).

Table 9. Perceptions of farmers about extreme weather and climate change expressed as percentages

Province	**Observation of changes in the weather /climate extreme events in the last 10 years (floods, monsoon delays, salt water intrusions etc)**			**(n)**
	None	Very much	Somewhat	
Dong Thap	3.8	77.4	18.9	53
Vinh Long	12.0	72.0	16.0	25
Can Tho	24.4	18.3	57.3	82
Tra Vinh	40.0	0.0	60.0	15
Soc Trang	33.3	0.0	66.7	15
Total (%)	36(19)	74(39)	80(42)	190

Also, the Chi-square test indicated that farmer perceptions on climate change did neither have any correlation with their "level of education" nor the "number of years they were involved in catfish farming or aquaculture. But some correlation was observed with the number of trainings the farmers attended (Chi-square value 20.54, significant at 1% level and Cramer's V statistic of 0.2325). This indicates that trainings increased farmer awareness to some extent about extreme weather and climate change. According to information provided by some respondents, commercial chemical companies and the provincial authorities organized training workshops for farmers in 2008-09. Some farmers expressed that the media (newspaper and TV) have been an important source of information about climate change and extreme weather events.

In the survey, farmers were requested to specify their concerns about risks from recent climate change and extreme weather changes (Table 9). This was mainly to analyze how farmers perceived the risks from climate change or extreme weather events. About 43 % of the farmers responded that they were "not concerned" while 51 % expressed that they were "very much concerned" and only 6% recorded that they were "somewhat" concerned about the risks to catfish farming from climate change and extreme weather events. This was also discussed with farmers and stakeholders at the focus group meetings when similar concerns were expressed (Truong et al. 2009).

A majority of farmers in two provinces namely, Dong Thap and Vinh Long were more concerned about climate change risks. The results from the Chi-square test showed that farmers were concerned about climate change and extreme weather event risks was very much influenced by the province to which they belonged (Chi-square value= 91.74 and Cramer's V= 0.49).

Further, the Chi-square test found that concern about risks from extreme weather events is not associated with years of aquaculture experience or education. However, a Chi-square test indicated (Chi-square value 17.89 and Cramer-V statistics= 0.18) some association between trainings undertaken and perception of risks from climate change (Table 10). To sum up, the above analysis indicates that farmer perceptions on climate change risks, and extreme weather events in the past 10 years was influenced mainly by the province to which they belonged.

Table 10. Farmer perceptions about risks due to extreme weather and climate change expressed as percentages

Province	**Concerns about recent extreme weather events**			**(n)**
	Not concerned	Very much	Somewhat	
Dong Thap	1.9	81.1	17.0	53
Vinh Long	12.0	76.0	12.0	25
Can Tho	65.9	34.1	0.0	82
Tra Vinh	100.0	0.0	0.0	15
Soc Trang	60.0	40.0	0.0	15
Total (%)	82(43)	96(51)	12(6)	190

6.5 Impacts to climate change and extreme weather events

Of the 190 farmers surveyed, 133 farmers (70 %) responded that they were personally "affected" by climate change or extreme weather events on one or more occasions in the past 10 years. Of those affected, 46 % indicated that the effect was "very serious" and 40 % felt that they were "somewhat affected" (Table 11). The responses in this case appeared to be very much related to his or her perceptions of the risks, either from direct damage to the farm during typhoons or floods or loss of fish stocks etc.

Farmers in Dong Thap and Vinh Long provinces expressed being more vulnerable and affected by climate change and extreme climate events than farmers in other provinces.

The magnitude of damage was also more in these two provinces, as evident from the responses. In Tra Vinh and Soc Trang provinces, the damage was not reported to be serious.

The results indicated that farmers in the two provinces Dong Thap and Vinh Long were more vulnerable and need to be prioritized for help to adapt to climate change and extreme weather events. The Chi Square test (Chi-square value 79.58) also showed that the differences between provinces when it comes to farmers overcoming losses and adaptation to extreme weather impacts were very significant.

Table 11. Frequency distribution of impact of climate change and extreme weather events on catfish farmers classified according to the provinces. The percentages of the responses are given in parentheses

	Province to which farmer belongs					Chi-Square Test ($P<0.01$)	Cramer's V
	Dong Thap	Can Tho	Vinh Long	Tra Vinh	Soc Trang		
Impact of Extreme Events							
Not affected by Extreme Events	3(2)	37(19)	2(1)	7 (4)	8 (4)	35.52	0.444
Affected Extreme Events	50 (26.5)	45 (24)	23 (12)	8 (4)	7 (4)		
Magnitude of damage of extreme events							
If affected/ was not serious	5(3)	45 (24)	6 (3)	8 (4)	12 (6)	58.12	0.391
Somewhat	19(10)	25(13)	7 (4)	7 (4)	3 (2)		
Very serious	29(15)	12(6)	12 (6)	0 (0)	0 (0)		
Difficulty in overcoming the losses							
Not very difficult	9(5)	58(31)	6 (3)	11 (6)	10 (5)	79.59	0.458
Somewhat difficult	20(11)	24(13)	6 (3)	4 (2)	5 (3)		
Very difficult	24(13)	0(0)	13 (7)	0 (0)	0 (0)		
Frequency of Extreme Events							

Less frequent	11(6)	6(3)	10 (5)	0 (0)	0 (0)	28.42	0.273
Same as before before before	13(7)	13(7)	6 (3)	4 (2)	4 (2)		
More frequent	29(15)	63(33)	9 (5)	11 (6)	11 (6)		

6.6 Adaptation strategies of farmers to climate change induced risks

Analysis of survey results indicated that about half (52 %) of the respondents have thus far not taken up any adaptation measures to address extreme weather events and climate change. Whereas, 48 % have reported that they have initiated some measures in an attempt to address risks from climate change. Out of these, 14 % of the farmers have changed farming practices, 6 % have shifted to other occupations, 4 % introduced new fish species, 3 % of respondents obtained help from the government, NGOs and other agencies and the rest followed other measures like using chemicals, decreasing stocking density etc. (Figure 14).

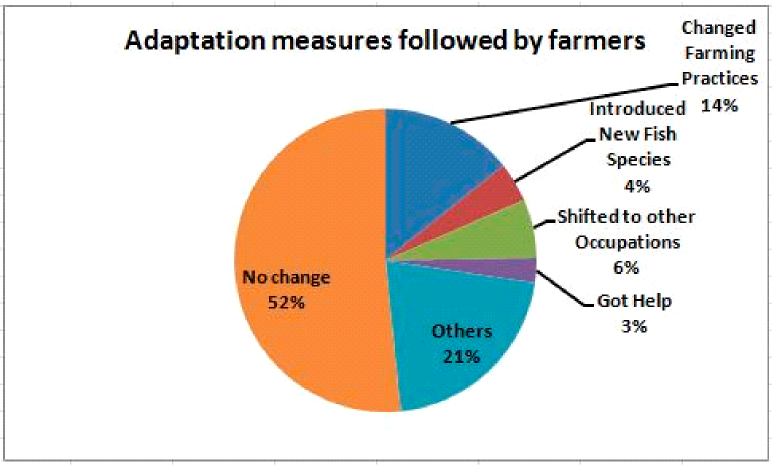


Figure 14: Adaptation measures followed by farmers in the surveyed areas

The survey also included questions related to farmers' planning and preparedness to address problems arising from potential climate change and extreme weather events. Of the 190 farmers surveyed, only 18 had plans to change their catfish farming practices to overcome expected troubles from climate change and extreme weather events. Similarly, 21 farmers had plans to farm new species, while the rest had no such plans. Only 2 farmers said that they will be going resorting to both changing farm practices and farming new species, and one farmer will be constructing bunds. About 21 farmers reported that they will be using other measures like, reducing stocking density, using chemical treatments, using new feed etc.

As a part of the survey, catfish farmers were also asked to rank the different agencies that according to their experience are capable of providing support for better adaptation.

Since fish processing companies was ranked only by two farmers, it was excluded from further analysis. The rankings were then converted into Garrett scores to evaluate the consistency of farmers in ranking the different agencies and then average scores for each variable was worked out (Table 12).

Table 12. Garrett Ranking of agencies that could help in planned adaptation.

Agency	Rank						
	1	2	3	4	Total Garrett Score	Average Score	Rank
DARD (Provincial agency of fisheries)	2972	702	44	27	3745	55.9	1
Aquaculture extension centers (DARD)	1068	398	207	0	1673	55.8	2
University/Research Institutes	873	441	587	81	1982	46.1	6
Farmers associations/ groups	768	696	155	108	1727	48.0	5
Drug and chemical companies	2079	211	93	0	2383	53.0	4
Pellet feed companies	1009	124	0	0	1133	56.7	3

Note: rank 1 is considered the best.

The analysis shows that farmers have trust in the DARD (Department of Agriculture and Rural Development of the Provincial Governments) as the most capable agency for providing support, followed by Feed and Chemical Companies.

6.7 Social vulnerability/resilience indicators to climate change of surveyed farmers

Vulnerability indicators are important as they can assist in the development of future strategies for adaptation and to improve the adaptive capacity of the farmers. With this assumption in view 'farm level vulnerability indices' were constructed in the study. This was done using PCA, where the first principal component was used to construct "regional vulnerability index" (Gbetibouo and Ringler 2009). It was also assumed that the variables used in the analysis were independent and influenced the vulnerability of the farmer either positively or negatively. For example, it was considered reasonable to assume that trainings provide the farmer with more capacity to address climate change and extreme weather events and so more trainings should mean that the farmer's vulnerability will be reduced. Similar functional relationships can be assumed between the other variables selected and vulnerability.

Table 10 gives the results of the PCA. It provides the coefficients of the 8 variables (considered as vulnerability indicators), their standard errors and component loadings. The component loadings provide the correlation coefficient between the variable and vulnerability index. The PCA identified the first 4 latent roots (of vulnerability indicators) with values greater than 1. These values together explain about 62 % of the variation. The first latent vector explains about 18 % of the total variation in the data set. Its coefficients were then used to construct 'vulnerability index' of the farmers.

Table 13. Socio-economic vulnerability indicators

Indicator Name	First latent vector	Standard Errors	t-value	Component loadings
Experience in fish farming	0.4941	0.2282	2.1653**	-0.588***
Trainings attended	0.4584	0.3836	1.195	-0.529***
Education level	0.4287	0.2173	1.9729**	-0.508***
Percentage of earning members in household	-0.4044	0.2905	-1.3922	0.437***
Number of farms	0.3788	0.2047	1.8505*	-0.365***
Land ownership	-0.0963	0.3052	-0.3155	-0.205*
Percent income from fish farming	-0.1884	0.3818	-0.4935	-0.191*
Age of the farmer	0.1008	0.5371	0.1877	-0.036

Significant at 10%; ** Significant at 5% and ***Significant at 1% level

The results from the PCA (Table 13) showed that the following socio-economic variables, viz., land ownership, % of earning members to household size, % income from fish farming, number of farms, educational level, trainings attended by the farmer and experience in fish farming were important determinants of catfish farm level vulnerability. The correlation coefficients between these variables and the ‘vulnerability index’ were all significant.

The component loadings given in the last column (Table 13) are the correlation coefficients of the vulnerability scores with respective indicators. As expected, all these indicators except percentage of earning members to household size have significant negative correlation coefficients with the vulnerability scores which implies that the higher the values of these indicators the lower the vulnerability of the farmer to climate change. Table 10 clearly shows that percentage of earning household members, number of farms, % income from fish farming, education level, training attended and experience in fish farming are all highly correlated to vulnerability of the farmer to climate change and extreme weather events.

6.8 Farm level vulnerability

The farm level vulnerability indices are the first principal component (PC) scores for each farmer. Thus there are 190 values and each one represents the ‘vulnerability of the farmer to climate change’ under the assumption that the variables listed above affect (either positively or negatively) the vulnerability of the farmer to climate change impacts.

After computing these indices, the association with an independent variable, viz., ‘difficulty of each farmer in overcoming the losses due to climate change’ was investigated. The responses are given in a 3 point scale representing ‘not difficult’, ‘somewhat difficult’ and ‘very difficult’. ANOVA shows that the means of vulnerability scores of the three groups were significantly different ($P < 0.001$). Thus vulnerability scores were correlated with the degree of difficulty overcoming losses due to climate change. The correlation coefficient between the vulnerability scores and farmers’ responses was 0.3298 which was significant ($P < 0.01$) and this also supports the conclusion that the two variables were correlated.

To further test the robustness of the analysis, the vulnerability scores were used to classify the farmers into five categories using normal distribution percentiles (20 %, 40 %, 60 % and 80 %). The number of farmers that fall in each category were computed and then they were post stratified based on their answers to ‘difficulty in overcoming losses due to climate change’. This exercise resulted in a two-way table (Table 14).

Table 14. Vulnerability level based on Principal component indicator and level of 'difficulty in overcoming losses due to climate change' of catfish farmers.

	DOL-0	DOL-1	DOL-2	Total
LV	21	15	6	42
MV	15	9	12	36
V	16	18	9	43
HV	6	12	10	28
VHV	7	14	20	41
Total	65	68	57	190

Note: LV=less vulnerable; MV=moderately vulnerable; V=vulnerable HV=highly vulnerable and VHV=very highly vulnerable and DOL=difficulty in overcoming losses due to climate change.

A chi-square test was performed to determine whether the two variables were independent or not. The computed value of Chi-square was 20.546 which was significant ($P<0.01$) indicating that the two variables were independent.

With the above statistical analysis we can conclude that the vulnerability of a farmer to climate change is closely related to the difficulty in overcoming losses due to climate change. Since the variables percentage household of earning members, number of farms, % income from fish farming, education level, training attended and experience in fish farming are significantly loaded on the first PC, they are related very much to the farmers difficulty to overcome losses to the damage from climate change and thus the vulnerability.

6.9 Discussion

The surveyed farmers represent small scale farmers typical in the region (Phan et al. 2009) that are likely to be affected by climate change and extreme weather events. The surveyed catfish farmers mostly belonged to one ethnic group (the Kinh). This is an important observation and relevant for consideration while planning for future adaptation strategies to help small scale farmers. Literature also supports the argument that homogenous groups are easier to organize as compared to heterogeneous groups with more ethnic diversity, diverse interests and conflicts. The level of literacy amongst the farmers was relatively high, as well the exposure to trainings. Both trainings and level of education have significant influence on vulnerability to climate change and extreme weather events.

The present study shows that the vulnerability of farmers is influenced by several factors. According to Gallopin (2006) vulnerability, resilience and adaptive capacity are closely linked. Vulnerability and adaptation capacity may differ from one region to another, and within a region there may be differences between communities or individuals (Gallopin 2006). In the study area, a majority of farmers in Dong Thap and Vinh Long provinces were found to be more affected by climate change and extreme climate events than farmers in other provinces.

Accordingly, the vulnerability of communities or farmers is determined by their location. A study made by O'brien et al. (2004), concluded that as scale differences are brought into consideration, vulnerability emerges within some regions, localities, and social groups. Their study showed that in order to cope with actual and potential changes in climate, it will be necessary to acknowledge vulnerabilities at the regional and local levels, and to address these accordingly.

In the present study, half of the farmers were yet to take up any adaptation measures. This shows that future strategies to improve resilience should focus on improving farmers' knowledge and skills not only in technical aspects of catfish farming, but also awareness on climate variability and measures to address the impacts. Overall, farmers in the study area have not planned well for overcoming future weather disturbances. This may be because most farmers were small scale, not well informed of potential climate change impacts, and are exposed to extreme weather disturbances very differently.

In Can Tho, Tra Vinh and Soc Trang provinces, the farmers did not find it difficult to adapt and overcome losses as compared to farmers in Dong Thap and Vinh Long. The latter two provinces incidentally were affected by more frequent extreme weather events and climate changes in recent years. Within a community there could be differences based on the farm size, the training exposures and education, the experience in aquaculture, the diversified income options to households, etc. that determine the vulnerability to any extreme weather or climate changes. In addition, level of access to resources affects households and communities capacity to adapt (social vulnerability). Differences in socio-economic status are known to affect vulnerability (Adger 2006;Nagothu 2007; Ly Dinh et al. 2009).

7. GHG emissions and resource use

7.1 Impact assessment results

Table 15 shows the GWP values of different aquaculture products. Shrimp (India) has the highest impacts, followed by pangasius (Viet Nam) and Milkfish (Philippines). When compared between shrimp and pangasius, the impact of shrimp is almost three times higher than pangasius as the consequences of GHG emissions related to the use of compound feed in feed production at the feed mill as well as the use of electricity in aerators at the shrimp farm (Figure 15). With respect to the feed production, the use of fish meal and wheat flour contributed dominantly to the GHG emissions.

Table 15: Life cycle impact assessment results

Aquaculture system	GWP (kg CO2e/t fish or shrimp)	EP (kg PO43-e/t fish or shrimp)
Pangasius (Viet Nam)	1,327.90	8.56
Shrimp (India)	3,676.47	1.43
Polyculture (Viet Nam)	153.51	0.72
Milkfish (Philippines)	6.04	0.0019

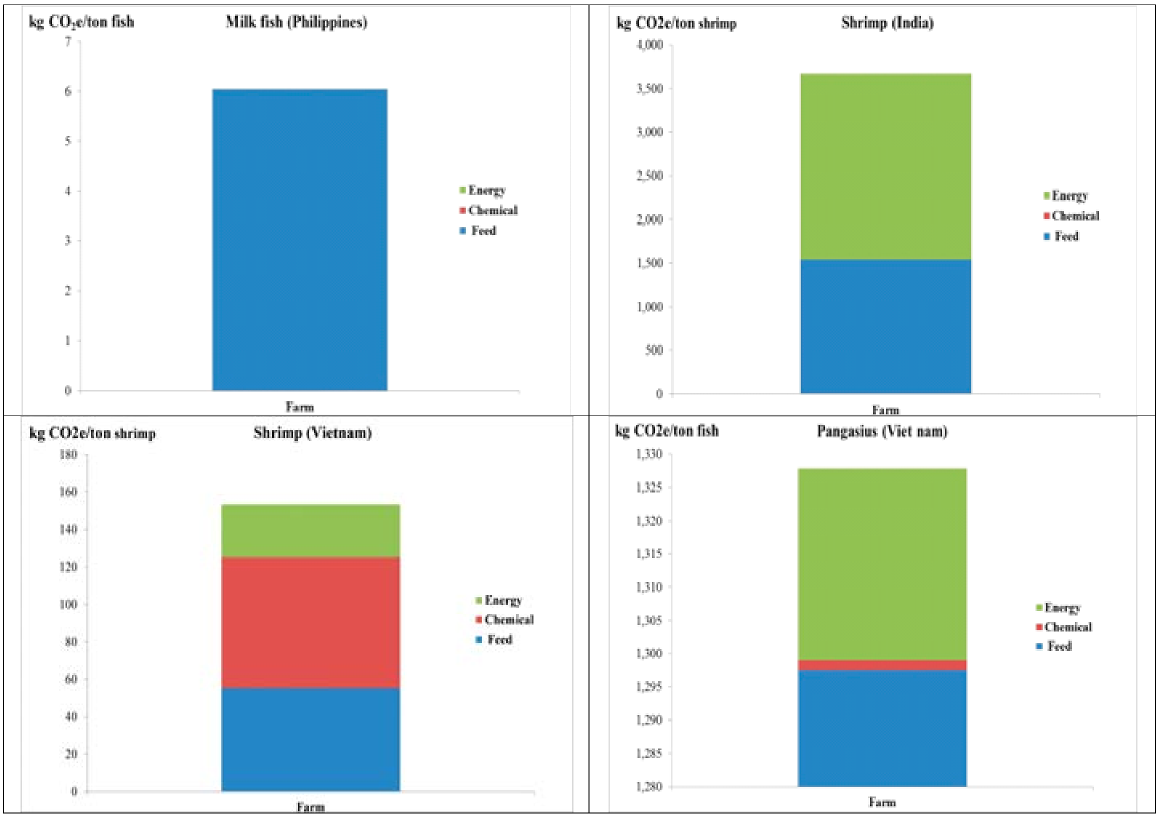


Figure 15: Contribution analysis of Global Warming Potential results of different aquaculture products

Figure 16 shows the comparative GWP figures of different aquaculture products. The level of GHG emissions of Indian shrimp is higher than Vietnamese pangasius catfish, and Filipino milkfish. Vietnamese pangasius and Filipino milkfish are much lower than the others, as it requires rather low level of inputs and no use of electricity.

The GHG emissions from aquaculture products are mainly from the use of compound feed and electricity for pumping water. Thus, the feeding management and the optimal operation of pumps must be given the attention in order to reduce the GHG emissions. More importantly, the potential impacts associated with feed ingredients especially fish meal and wheat flour should be taken into account at the feed mill. The energy performance of pumps used should also be considered at the farm, i.e. pumps with high-energy efficiency are preferred with the monitoring of optimal level of water quality in ponds.

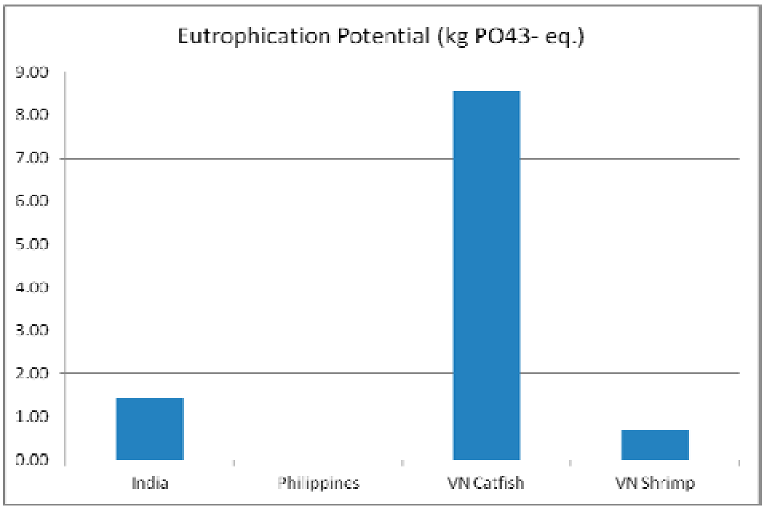


Figure 16: Contribution analysis of Eutrophication Potential results of different aquaculture products

7.2 Analysis of feed resource 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 fertilisers. 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.

7.3 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.

For the purpose of this study, 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;

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

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

Table 16. Results of AquaClimate case study analysis for FIFO Ratio

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

The difference between the Indian and Vietnamese polyculture FIFOs is in large part because the Vietnamese system depends on natural productivity rather than feed input; catfish and milkfish FIFO is low because they are omnivorous/herbivorous and can be grown on lower protein diets / algal mats

There is a difference in the intensities of the production systems. Vietnamese improved extensive polyculture and Philippine Milfish ststems are ‘low' intensity shrimp culture systems Indian improved extensive shrimp are ‘medium' intensity culture systems and Pangasius catfish culture systems are very intensive culture systems.

7.4 Analysis of water Resource 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 m^3 (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 brackishwaters unsuitable for agriculture; plus, integrated, land-based saltwater faming is possible (Fedoroff et al., 2010).

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

$$\text{Water use index, m3/t} = \frac{\text{Water use, m}^3}{\text{Production, t}}$$

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.

Table 17.Results of AquaClimate case study analysis for water use

Case study culture system	**m^3/t**
Polyculture pond culture, Vietnam	47,500
Shrimp pond culture, India	12,633
Milkfish pond culture, Philippines	8,010
Pangasius pond culture, Vietnam	1,327

There is a difference in the intensities of the production systems. Vietnamese shrimp systems are ‘low' intensity shrimp culture systems Indian shrimp and Philippine milkfish are ‘medium' intensity culture systems and Pangasius catfish culture systems are very intensive culture systems.

7.5 Analysis of land resource use

Aquaculture uses land in two ways. First, aquaculture facilities occupy a defined area or space on land or in water; however, facility area accounts for only a portion of the total land or water area needed to produce an aquaculture crop. Additional ecosystem area is needed to provide support or service functions. The two most important of those functions are food production and waste treatment (Boyd, 2006; Boyd and Polioudakis, 2006).

Table 18. Results of AquaClimate case study analysis for land use

Case study culture system	m^2/t
Polyculture pond culture, Vietnam	80,594
Shrimp pond culture, India	5,543
Milkfish pond culture, Philippines	2,339
Pangasius pond culture, Vietnam	24.16

The large land use by polyculture farming in Vietnam again reflects the very low intensity of the system.

7.6 Analysis of energy resource 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 aquaculture production should be conducted for a number of species and culture methods.

Table 19. Results of AquaClimate case study analysis for energy use

Case study culture system	MJ/t
Shrimp pond culture, India	4,358
Pangasius pond culture, Vietnam	1,287
Polyculture pond culture, Vietnam	517
Milkfish pond culture, Philippines	2

The Indian shrimp culture system has a much larger energy use compared to the other culture systems due to the use of pumps and aerators. Al though Pangasius catfish culture also uses pumps for water exchange, Pangasius catfish energy use is surprisingly efficient because of the economies of scale offered by its extreme intensity. The Vietnamese polyculture and milkfish power use is low because they don't use aeration and/or are system is tidally fed.

7.7 Analysis of wild seed and broodstock resource use

Capture-based aquaculture (CBA) does not have full control of the life cycle and relies on the collection of seed, fry, fingerlings or broodstock from the wild. In other cases a proportion of the seed is still collected from the wild as there is insufficient production of seed from hatcheries or broodstock collected from the wild as it is difficult to condition mature broodstock artificially.

It is also used on low-value fish species that are sometimes extensively farmed with minimum inputs. The main concern related to the collection of wild seed or broodstock is whether the wild fishery has a negative impact on wild stocks of the targeted species as well as non-targeted species.

Much is still unknown about early life history stage dynamics, however it is assumed that there is some degree of linkage between seed collection and adult fisheries particularly when billions of seeds taken each year such as was the case for milkfish.

Traditionally, aquaculture enterprises in the Mekong Basin were capture-based. Large numbers of tra catfish larvae (P*angasianodon hypophthalmus*) were, until recently, caught in the upper Mekong delta near the border between Viet Nam and Cambodia. The fishery was concentrated in Chao Doc and Tan Chau districts of An Giang Provinces in Viet Nam. Estimates from 1977 suggest that 200 to 800 million fry, 0.9–1.7 cm in length, were caught annually (based on data from An Giang Department of Agriculture, cited in Trong, Hao and Griffiths, 2002). Tra catfish were first artificially propagated in Thailand in 1959, and the technology has since spread throughout south-east Asia (Trong, Hao and Griffiths, 2002).

However the aquaculture of Pangasiid catfishes is now largely based on hatchery produced seed. In 2006 there were 130 hatcheries (An Giang 15; Can Tho 5; TienGiang 4; Vinh Long 3; and Dong Thap 103) in the Mekong Delta region of Viet Nam producing 10 billion catfish larvae and the production of tra catfish fingerlings reached 1 billion

8. Trade-off analysis

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.

8.1 Policy framework based on farmer group's prioritizations

The main two climate change issues for the farmer group were increase in water level and flooding (49.4%) along with irregular seasons (40.7%). The adaptation measures to deal with increase in water level and flood were primarily increase in pond dike height (65.2%), improvement in water quality (26.7%) and improvement in feed quality (8.2%). For irregular seasons the main adaptation measure was improving seed quality (46.4%) followed by improvement in feed quality (28.4%) and water treatment (25.3%). The farmer group also identified hot seasons as a climate change issue (9.9%) with three adaptation measures: removal of sediments (56.6%), making ponds deeper (32.4%) and increasing water exchange (11%) (Figure 17).

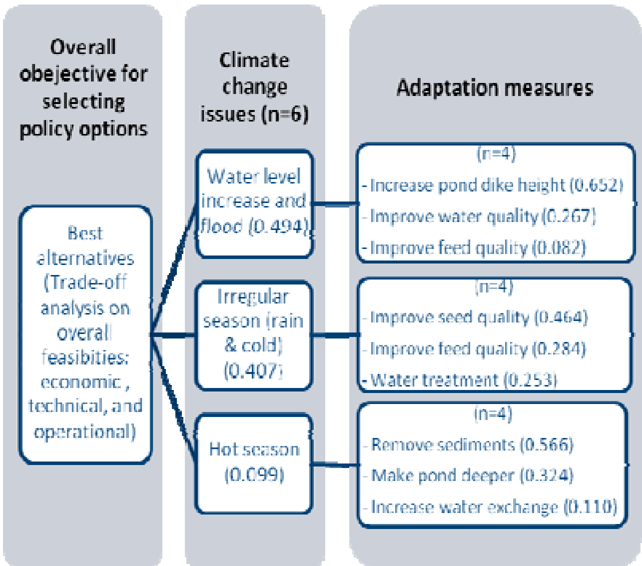


Figure 17: Policy framework based on farmer group's prioritizations

Table 20. Climate change issue ranking comparison between stakeholder groups

Climate change issue	Ranking by stakeholders		
	Farmer	Science and technology	Policy and institution
Water level increase	1	4	3
Irregular season (rain & cold)	2	1	1
Hot season	3	3	4
Salt water intrusion	NA	2	2

Table 20 shows that irregular season has received relatively high ranking among other climate change issues (Ranking number 1 for science & technology group and policy and institution group and number 2 for farmer group). Policy makers should pay more attention to this climate change issue in order to mitigate and reduce the impacts from irregular season and at same time to harmonize with the stakeholder's prioritizations.

For salt water intrusion, science and technology group and policy and institution group ranked this climate change issue as number two while farmer group did not acknowledge this issue in the ranking. This gradual impact caused by salt water intrusion may not be observed easily by farmers. Information about this climate change issue should be disseminated and shared among the stakeholders so that the main stakeholder like farmers will understand the impacts and be able to prevent those impacts as well as participate in policy implementation.

The rest of the climate change issues should be discussed further among stakeholders in detailed since different levels of stakeholder's preferences based on different experience and expertise.

8.2 Policy framework based on science and technology group's prioritizations

The main climate change issues for the science and technology group was irregular seasons (50.3%) and the adaptation measures were sharing of knowledge about farm management and technology (43.8%) followed by enhancement of the health and resilience of fish stocks (30%). Further adaptation methods were a closed system (14.3%) and environmental monitoring (11.9%) There were three other climate change issues that were rated with similar importance to each other – salt water intrusion (19.2%), hot seasons (16.5%) and increase in water level and flooding (14%). For salt water intrusion the adaptation methods were crop calendar management (33.1%) and use of alternative species (32%). There was also selection of the best strain that is salinity tolerance (24.4%), and a closed system (12.6%). In response to hot seasons the main adaptation measures were a closed system (37.8%) and introduction of a new catfish species (33.4%). Other adaptation methods were crop calendar management (18.2%) and aeration systems (10.6%). In the case of increased water levels and flooding, crop calendar management (51.6%) was the most important adaptation measures followed by environmental monitoring (22.6%), strengthening dikes (16.8%) and bio-security to prevent spread of disease (8.9%) (Figure 18).

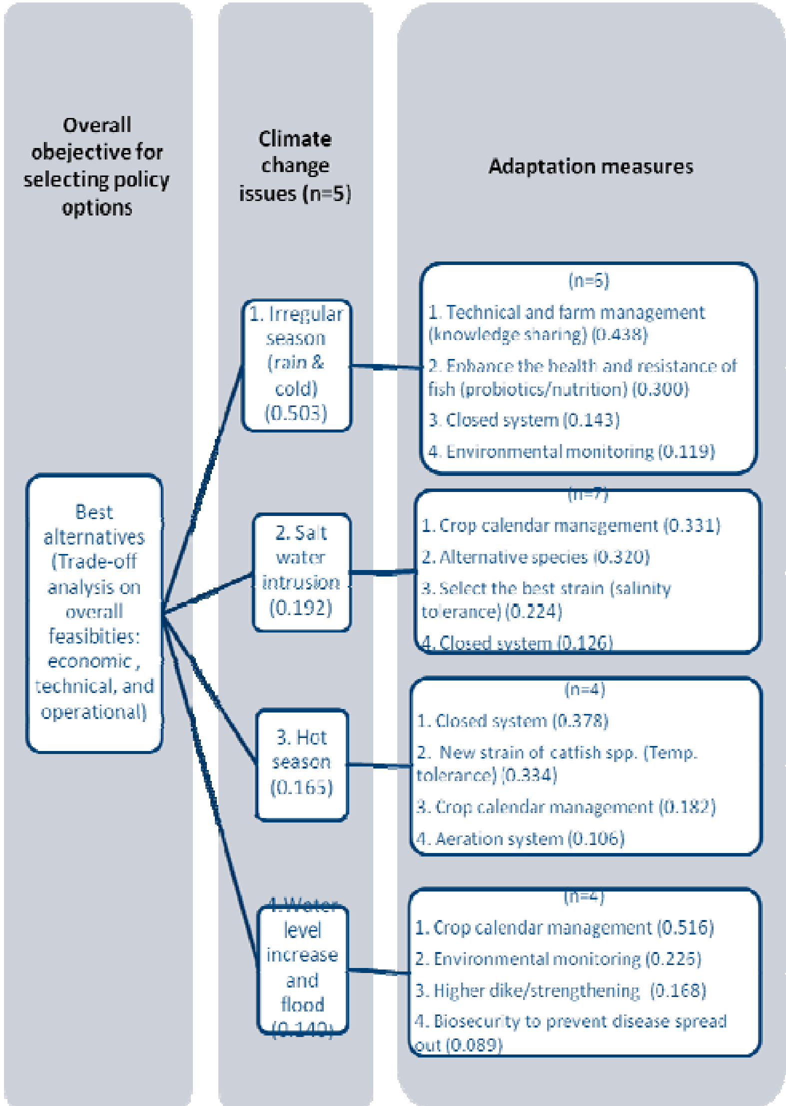


Figure 18: Policy framework based on science and technology group's prioritizations

8.3 Policy framework based on policy and institution group's prioritizations

The main climate change issue for the policy and institution group was irregular seasons that related to rain and cold weather (56.3%) with the main adaptation measure to take advice from experts (52.2%) followed by improving seed quality (24.8%) and development of vaccines (23.0%). There were three other issues of similar importance – salt water intrusion (16.9%), increase in water levels and flooding (14.4%) and hot seasons (12.4%). For salt water intrusion there were four adaptation measures with similar priority, namely improvement of local and national linkages (27.5%), aquaculture planning (27.4%), and introduction of tolerant species (23.6%) and use of expert scientific advice (21.5%). In the case of increase in water levels the adaptation measures were greater government investment (41.2%), improved advice and communication

(23.9%) and the need for research (18%) and training (17%). The adaptation measures in response to hot seasons were area zonation for Tra Catfish culture (40.1%), environmental monitoring (24.0%), use of floating aquatic plants (18.0%) and crop calendar management (17.9%) (Figure 19).

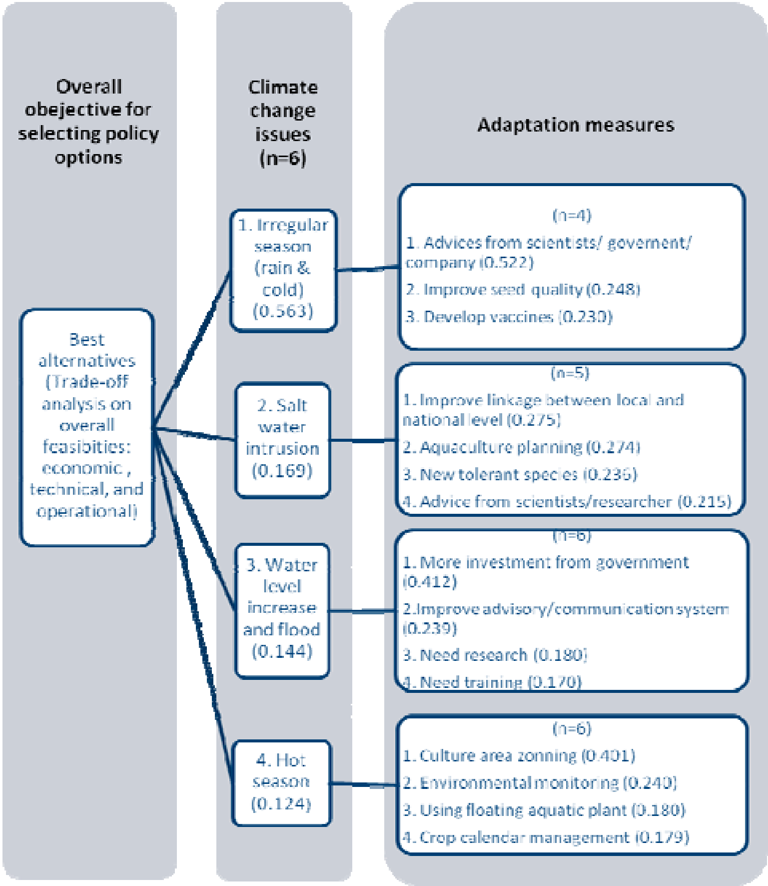


Figure 19: Policy framework based on policy and institution group's prioritizations

The farmer group was focused on actions such as cleaning the water and reducing sediment in addition to improving the height of the dike. There was also priority allocated to improving the quality of seeds and feed used. The science and technology group were more focused on the management of farms and crop cycles (calendar). The policy group priority was to get scientific advice and to undertake research and training as part of the overall planning.

The farmer group placed the highest priority on practical measures that could be implemented reasonably quickly while the other two groups placed greater emphasis on developing management strategies to dealing with the impact of climate change rather than reacting to each individual change separately.

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

9. Conclusion and recommendations

Striped catfish farming is considered as quite a highly productive system in the whole stream of the lower Mekong river in Vietnam. The different zones were different in terms of their climate change impacts, productivity, culture system and socio-economic characteristics.

Catfish farmer's perception was different between different zones and specific climate change impacts. Some recent extreme weather and climate changes in temperature, precipitation, irregular weather and salt water intrusion were observed by catfish farmers in the Mekong Delta.

Overall, stakeholders perceived climate change as a threat to aquaculture in general and catfish farming in particular. Though farmers have started to adapt to the extreme weather events, their socio-economic context makes them vulnerable to climate variability. Stakeholder's priority was to improve the adaptive capacity through strengthening the current culture systems, producing good quality fry, funding support in the event of losses, training and supporting small scale farmers with necessary resources.

Farmers' suggestions included changes in management practices, producing and using good quality seed, developing new/improved culture systems/species, improved infrastructure, livelihood diversification, training and awareness workshops, financial support, and zoning and timing for culture area. In addition, improving adaptive capacity; developing early warning broadcast systems for RLS, flood & supporting small scale farmers with necessary resources were also recommended by some farmers.

A long-term strategy for catfish production is recommended that salt tolerant seed production need to be researched to produce salt tolerant fingerling of catfish for sensitive area with saline water intrusion. In addition, hydraulic modeling should be applied for water flow prediction in the lower Mekong river, Vietnam.

9.1 Policy recommendations

- It needs to set up standardized environmental monitoring and weather forecasting systems.
- Design and implement training and capacity building courses on climate change impacts
- Provide access for credit and crop insurance to small scale cat fish farmers

- Strengthen co-ordination and cooperation between stakeholders
- Increase research funding to address climate change impacts assessment and adaptation

9.2 Farmer recommendations

- ***Provincial managers*** should provide better aquaculture planning and zoning, especially catfish farming and this should be carried out by Department of Agriculture and Rural Development (DARD). Besides, the current irrigation canal system needs to be improved better in order to bring freshwater to farms. This should be done by Department of Irrigation. Forecasting and monitoring system for river level rise and flood need to be established by Department of Natural Resources and Environment (DONRE), as well as improving early warning broadcast system by TV stations. In addition, the main river and canal dikes need to be maintained and strengthened. This should be invested by Department of Environment and Natural Resources, Department of Agriculture and Rural development, Institute of Irrigation at Provincial level.
- Scientists and technology research institutions should research and develop fry and fingerling free of disease seed, disease diagnosis and treatment, vaccines against the major diseases, as well as improving quality of fingerlings. In addition, research to select salt and higher environmental change tolerance catfish strain that needs to be implemented by University and Research Institutes. They should provide training on using appropriate chemicals and drugs.

9.3 Science and Technology recommendations

- ***Training farmers and staff*** should be carried out to adapt with climate change impacts on catfish culture in the Mekong Delta. This should be implemented by each Department of Agriculture and Rural Development and assisted by Universities and Institutes in the Mekong Region.
- ***Vaccines development for treatment of major diseases and health management in catfish*** need to be carried out by scientists to prevent from serious diseases and increase fish health and resistance in long term development in the Mekong Delta. This need to be funded by Government and NGOs as well as chemical and drug companies.
- ***Identifying species for polyculture in catfish pond*** should be researched and advised by scientists to salvage feed waste and reduce water pollution in catfish ponds in the Mekong Delta.

- ***Selective fish breeding for saline and environmental tolerance*** need to be studied by Universities and Institutes to increase fish tolerance in saline water intrusion and environmental changes, especially climate change for further catfish industry development.
- ***Improving fingerling quality*** should be carried out by Universities and Institutes as well as Government and private hatcheries to provide good quality of fingerling for catfish farmers and maintain fish production under climate change condition.

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Annex 1. Generic 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 slow	Converging. Service and information economy	Intermediate economic growth. 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 kgCO2e meaning kg CO2 equivalent, as equivalent to 26 kg of CO2 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:

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

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.

The Production Function Estimation:

Based on the general aquaculture production economic concept, the production function can generally be set as:

Aquacultural output (monetary / weight unit) = f(group of socioeconomic variables, group of aquaculture production variables, and group of climate change perception indicators).

The group of socioeconomic variables is composed of the variables that can represent the socioeconomic aspects of each operator (e.g. gender, age, educational background, skills and experience in aquaculture activity). The group of aquaculture production variables can be divided further into 2 subgroups; aquaculture technique and management data (e.g. total farm size, pond size and number of fry stocking) and incurred aquaculture costs (e.g. total seed cost, total commercial feed cost and total chemical cost). The group of climate change perception indicators can represent each operator's perception on any incident that being related with the climate change impact.

Group of Socioeconomic Variables (Example):

1. Owner's age (year)

2. Number of year in aquaculture (year)
3. Farm age (year)

Group of Aquaculture Production Variables:

Aquaculture Technique and Management Data (Example)

4. Crop stocking density 1 , 2 (1,000 fry/ha)
5. Fry size crop 1 , 2 (cm)
6. Crop duration 1 , 2 (month)
7. Crop survival rate 1 , 2 (%)
8. Pond area (ha)
9. Pond depth (ha)
10. Water depth (m)
11. Pond age (year)
12. Number of Crop in 1 , 2 year(s) (crop)
13. Number of seed per pond (1,000 fingerlings)

Incurred Aquaculture Costs (Example)

1 Total seed cost (million VND)

2 Total commercial feed cost (million VND)

3 Total homemade feed cost (million VND)

4 Total vitamin cost (million VND)

5 Total chemical cost (million VND)

6 Total drug cost (million VND)

7 Total fuel cost (million VND)

8 Total electricity cost (million VND)

9 Total temporary labor cost (million VND)

10 Total permanent labor cost (million VND)

11 Total sediment removal cost (million VND)

14. Total maintenance and repairing cost (million VND)

Group of Climate Change Perception Indicators (Example):

1 Flood experience (yes/no)

2 Irregular weather (yes/no)

3 Typhoon/heavy rain/storm (yes/no)

4 Temperature fluctuation (yes/no)

5 Salinity (yes/no)

6 Others (yes/no)

7 Change in temperature (gradual impact) (yes/no)

8 Change in precipitation (gradual impact) (yes/no)

9 Change in season (gradual impact) (yes/no)

10 Water pollution (gradual impact) (yes/no)

11 River/canal level rise (gradual impact) (yes/no)

12 Wind change (gradual impact) (yes/no)

13 Others (gradual impact) (yes/no)

14 Personal experience on extreme weather events in last 7 years (gradual impact) (yes/no)

The 1st multiple regression technique can be performed in order to select the best production function from the best statistical performance of each case study. The derived aquaculture production function can demonstrate the statistically significant relationship, if any, between aquaculture input(s) and output.

The Cost & Benefit Analysis (CBA):

The CBA in this project can be performed along with both production function estimation and trade-off analysis. The essence of CBA is to calculate the difference between the cost being spent for aquaculture production and the revenue earned from selling their production to the market. The general formulation for CBA calculation is:

Net Revenue or Profit (π) = Total Revenue (TR) – Total Cost (TC)

The TR can be calculated by multiplying a price of aquaculture product with an amount of aquaculture product. A unit of TR can be 'per crop and per area' to make it easy for comparing across different regions.

The TC can be divided further into 2 groups; Total Fixed Cost (TFC) and Total Variable Cost (TVC), respectively. A unit of TC can be 'per crop and per area' to match with the TR calculation.

The calculated NR or profit can be used as the baseline profit before any climate change adaptation being proposed (Work package II).

The Trade-off Analysis (TA) incorporated with Cost & Benefit Analysis:

The derived aquaculture production function can be used to identify the statistically significant inputs for aquaculture production for each case study. The 2nd multiple regression can be performed by setting the function as:

Selected statistically significant input = f(group of climate change perception indicators)

As before, the group of climate change perception indicators can represent each operator's perception on any incident that being related with the climate change impact. The linkage between the selected significant input and climate change perception can be determined. The most common climate change linkage can be selected and further investigated on any feasible adaptive measures or mitigation technique via TA (Sharing input with Work package III – IV)

The TA can be performed by using the CBA to compare the feasibility, efficiency and net return among different adaptive measures or mitigation techniques. The CBA can be used to calculate and compare the net return of each adaptive measures and mitigation techniques along with other considerations about the feasibility and efficiency in the short and long run (inputs for Work package IV).

The flow diagram of aquaculture Production Function Estimation and derivatives is presented in figure below.

Aquaculture Production Estimation (1^{st} multiple regression)	
List statistically significant variable(s) for aquaculture production	Cost & Benefit Analysis (CBA): Work-package II

Linkage between Selected Statically Significant variable(s) and group of climate change perception indicators (2^{nd} multiple regression)	
Identify/Quantify the linkage between these variables	Analysis on the impact /risk from climate change for sharing inputs: Work-package III-IV

Selection of Statistically Significant Variable(s)	
To optimally select the variable(s) that can lead to any adaptive/mitigation measures with the Trade-Off Analysis incorporated with CBA	Trade-Off Analysis incorporated with CBA of key (policy) option for Work-package IV

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;

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

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:

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

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[1] 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:

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

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

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

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.

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1 Perfectly competitive market and rational maximizer assumptions have been applied.

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:

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

(5)

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

(6)

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

(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:

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

(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:

$$FCR = \frac{Total\ Feed\ Mass(kg)}{Total\ Body\ Mass(kg)} \Rightarrow mFCR = \frac{Total\ Feed\ Mass(kg) * Feed\ Cost(value/kg)}{Total\ Body\ Mass(kg) * Fish\ Price(value/kg)}$$

(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.[2] 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.

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;

[2] '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).

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. Achievement of the case study

Items	**Titles**	**Conferences/Journal**	**Location**
Posters'presentation	1- Understanding the impacts, vulnerability and adaptive capacity to climate change of catfish (*Pangasianodon hypophthalmus*) pond farmers in the Mekong Delta, Vietnam *Truong Hoang Minh[1], Nguyen Thanh Phuong[1], Udaya Sekhar Nagothu[2], Varunthat Dulyapurk[3], Methee Kaewnern[3], Sirisuda Jumnongsong[3], Patrick White[4], Nigel W. Abery[5] and Sena S. De Silva[5]* 2- A Comparison on technical and economic aspects in striped catfish (*Pangasianodon hypophthalmus*) pond culture between freshwater and	International Conference on Environmental and Agricultural sustainability in the Mekong Delta National Student's Conference on Aquaculture and Fishery	Can Tho University (25-27 March 2010) Can Tho University (26-28 May 2010)

	saline water intrusion zones in the Mekong Delta, Vietnam *Lam Truong An, Truong Hoang Minh & Nguyen Thanh Phuong* 3- Potential climate change impacts on social vulnerability and adaptive capacity of striped catfish (*Pangasianodon hypophthalmus*) farming community, Mekong Delta, Vietnam *Truong Hoang Minh[1], Nigel W. Abery[2], Nguyen Thanh Phuong[1], Udaya Sekhar Nagothu[3], Sena S. De Silva[2]*	Global Conference on Aquaculture	Phuket, Thailand (22-25 Sept. 2010)
Oral presentation	Weather change and saline water intrusion impacts on rotation rice-shrimp (*Penaeus monodon*) farming system in Bac Lieu province, the Mekong Delta *Pham Minh Tien & Truong Hoang Minh*	National Student's Conference on Aquaculture and Fishery	Can Tho University (26-28 May 2010)
Papers	Comparison of catfish (*Pangasianodon hypophthalmus*) pond culture between freshwater and saline water intrusion areas in the Mekong Delta *Lam Truong An, Truong Hoang Minh & Nguyen Thanh Phuong*	Scientific Journal of Can Tho University Scientific Journal of Can Tho University	347-359,Vol. 14b 2010

	Weather change and saline water intrusion impacts on rotation rice-shrimp (*Penaeus monodon*) farming system in Bac Lieu province, the Mekong Delta *Pham Minh Tien & Truong Hoang Minh*		394-406,Vol. 14b 2010
Academy	- MSc. student on Aquaculture graduated in Can Tho University (*Mr. Lam Truong An*) - BSc. student on Fisheries Management graduated in Can Tho University (*Mr. Pham Minh Tien*)	Defended in Sept. 2010 Defended in May. 2010	Grade: 9.1/10 (A) Grade: 9.7/10 (A)