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Aquaculture Adaptation to Climate Change in Vietnam's Mekong Delta

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Abstract

Most of the aquaculture production in South-east Asia occurs in the floodplains and coastal areas that are highly exposed and vulnerable to climate change impacts and sea-level rise (SLR). This chapter presents an example of economic estimation of autonomous adaptation by shrimp and catfish farms in the Mekong Delta of Vietnam. It illustrates how planned adaptation measures can help defray catfish farmers' escalating costs of raising pond dykes in response to increased flooding in the delta. It also indicates that government policy and public investment into planned adaptation towards climate change impacts, particularly for water resources management, would necessarily take account of socio-economic development targets of the aquaculture industry. From these analyses, broader implications of plans for water resources management in the delta on the prospects and challenges to the aquaculture sector are discussed. In the long term, a 'no-regrets' strategy of reducing the high dependence on shrimp and catfish culture and diversifying into more ecologically oriented production systems can also hedge the aquaculture industry against the increasing risks and uncertainties brought about by climate change.

9.1 Introduction

Aquaculture is one of the fastest-growing animal food-producing sectors in the world. In the last three decades (1980–2010), production of farmed food fish increased 12-fold, at an average annual rate of 8.8% (FAO, 2012). The Asian region accounts for almost 90% of total aquaculture production and one-third of its global seafood export value (estimated from FAO online statistics). Excluding China, over half of the exported aquaculture products from Asia (accounting for almost two-thirds of the continent's global seafood export value) are produced in Bangladesh, Indonesia, the Philippines, Thailand and Vietnam. Most of the aquaculture production in South-east

Asia occurs in the floodplains and coastal areas that are highly exposed and vulnerable to climate change impacts – not only the direct climatic parameters, such as temperature and rainfall patterns, but also SLR and consequent flooding and coastal salinity intrusion. These impacts will have significant economic as well as social costs to those who directly and indirectly depend on the aquaculture industry for their livelihoods.

Adaptation is an imperative for enhancing the resilience of this economically important and dynamic sector. Aquaculture operators will, and do, respond to changes in land and water availability, market incentives and commodity prices by changing farm practices or even altering culture

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species and production systems. All of these constitute autonomous adaptation, where actors respond 'spontaneously' to change triggers (Adger *et al.*, 2007). Climate change and its attendant hydrological and coastal phenomena constitute additional environmental triggers to which farmers have to respond and adapt. By implementing these changes at the farm level, individual farmers will have to incur incremental capital investment and operational costs.

In 2010, a study was conducted by a WorldFish team to estimate the costs of autonomous adaptation by shrimp and catfish farms in the Mekong Delta of Vietnam (Kam *et al.*, 2012). This chapter extracts and examines the main findings of the study and discusses broader implications of plans for water resources management in the delta, in light of climate change and future land use, on the prospects and challenges that the aquaculture sector in the delta would face and the possible response strategies.

9.2 Current Status of the Aquaculture Industry in the Mekong Delta of Vietnam

The Mekong Delta of Vietnam, with its intricate system of canals, embankments and water-control structures, provides a mosaic of freshwater, brackish-water and marine environments that accommodate diverse aquaculture systems producing a variety of fish, crustacean and mollusc species (Table 9.1).

Presently the aquaculture industry in the delta is dominated by culture of the brackish-water shrimp (predominantly the black tiger shrimp, *Penaeus monodon* and with an increasing presence of the Pacific white leg shrimp, *Litopenaeus vannamei*) and the freshwater striped catfish (*Pangasianodon hypophthalmus*) – the two most important fish food commodities of Vietnam with a total export value of almost US\$4bn in 2012,¹ accounting for about 4% of the national Gross Domestic Product (GDP). The Mekong Delta accounts for about 80% and 98% of the total shrimp and catfish export values, respectively (GSO, 2008).

The spatial distribution of brackish-water shrimp and freshwater fish culture in the delta (Fig. 9.1) is influenced by its hydrological regimes, which result from a combination of local rainfall, seasonal discharges of the Mekong River into the delta and tidal effects from the sea.

Prolonged deep flooding occurs in the upper delta from July to December (Tuan *et al.*, 2007) as a result of the rainy season (May–October) coinciding with the high flow period (June–August), while the coastal zone experiences salinity intrusion from December to May (Tuan *et al.*, 2007) as a result of the dry season (November–April) coinciding with the period of low flows (February–April). High tidal ingress up the river branches of the delta aggravate flooding in the upper delta as well as salinity intrusion in the coastal zone.

Brackish-water shrimp culture in ponds is carried out in the salinity-affected areas in the coastal zone (Fig. 9.1) at improved extensive, semi-intensive and intensive scales, which are differentiated by stocking rates and feeding regimes. Presently the improved extensive system covers the largest area and occurs mainly in the salinity-affected intertidal zone of Ca Mau and Bac Lieu provinces. In areas further away from the intertidal zone there have been shifts to semi-intensive and intensive shrimp culture with mechanical aeration and water recirculation to maintain high stocking densities for high yields. Shrimp–rice aquaculture is practised in areas where a dual brackish and freshwater regime is maintained, particularly in parts of the south-western Ca Mau peninsula where a system of sluice operations and temporary dams allow sea water to intrude during the dry season for shrimp and to be flushed out during the rainy season for rice² (Hoanh *et al.*, 2009).

Catfish culture is concentrated in the inland provinces of An Giang, Dong Thap and Can Tho in the upper delta where freshwater supplies are ample (Fig. 9.1). Catfish ponds are located close to rivers and canals for ease of constant pumping to have a high level of water exchange for the intensively cultured system. As these areas are subjected to seasonal flooding, catfish ponds

Table 9.1. Diversity of aquaculture production systems and farmed species in the Mekong Delta, Vietnam.

Production system	Culture species	Extent and location
Brackish-water shrimp-based systems		
Pond monoculture at improved extensive (IE), semi-intensive (SI) and intensive (IN) scale	Hatchery <i>Penaeus monodon</i> at IE, SI and IN scale; hatchery <i>Litopenaeus vannamei</i> at IN scale	300,000 ha IE in Ca Mau and Bac Lieu provinces; 18,000 ha SI in Bac Lieu, Soc Trang and Tra Vinh; 22,000 ha IN in Soc Trang, Tra Vinh and Ben Tre
Shrimp–rice rotation (dry-season shrimp monoculture)	Hatchery <i>Penaeus monodon</i>	100,000 ha in Ca Mau, Bac Lieu, Soc Trang and Kien Giang
Shrimp–crab pond culture	Hatchery <i>Penaeus monodon</i> ; hatchery <i>Scylla serrata</i>	Ca Mau, Ben Tre, Kien Giang and Tra Vinh
Mangrove–shrimp	Wild seeds supplemented with hatchery <i>Penaeus monodon</i>	20,000 ha in Ca Mau; other provinces: Ben Tre, Kien Giang, Tra Vinh
Mangrove–shrimp–mud crab; mangrove–shrimp–mud crab–blood cockle	Wild seeds supplemented with hatchery <i>Penaeus monodon</i> ; hatchery <i>Scylla</i> sp.; <i>Anadara granosa</i> spats	30,000 ha shrimp–mud crab in Ca Mau; 850 ha of mixed culture with blood cockle
Other brackish-water aquaculture systems		
Cockles and clams: bed culture on intertidal mudflats for blood cockle; sandy beaches for clams	<i>Anadara granosa</i> , various clams	Ben Tre, Soc Trang, Tien Giang, Kien Giang and Tra Vinh
Pond or tank monoculture of eel	<i>Anguilla mamorata</i>	2000 ha in Ca Mau
Mud-skipper: pond monoculture; in rotation with shrimp, mud-crab and <i>Artemia</i> ; integrated with shrimp and mud crab	<i>Pseudapocryptes elongatus</i>	150 ha in Bac Lieu and Soc Trang
Freshwater catfish culture systems		
Pond monoculture of river catfish at highly intensive scale	<i>Pangasius hypophthalmus</i> (cá tra)	4500 ha in An Giang, Dong Thap, Can Tho and Vinh Long
Cage and pen monoculture of catfish at highly intensive scale	<i>Pangasius bocourti</i> (cá basa), <i>Pangasius hypophthalmus</i> , <i>Clarias gariepinus</i> × <i>Clarias macrocephalus</i> (hybrid catfish)	An Giang and Dong Thap

Continued

Table 9.1. Continued.

Production system	Culture species	Extent and location
Other freshwater fish culture systems		
Intensive pond culture of climbing perch	<i>Anabas testudineus</i>	Can Tho city
Pond, cage, hapa and tank monoculture of snakehead	<i>Channa</i> spp.	An Giang, Dong Thap, Can Tho and Kien Giang
Cage and pond-intensive monoculture of tilapia	<i>Oreochromis niloticus</i> (black and red tilapia)	Tien Giang and An Giang
Low- to semi-intensive polyculture of carp	<i>Cyprinus carpio</i> (common carp), <i>Ctenopharyngodon idella</i> (grass carp), <i>Chirrhinus molitorella</i> (mud carp), <i>Hypophthalmichthys molitrix</i> (silver carp)	Hau Giang, Can Tho, Vinh Long, Ben Tre, An Giang and Dong Thap
Fish polyculture in rice fields	Tilapia, common carp, silver carp, <i>Pangasius</i> catfish, <i>Helostoma temminckii</i> (kissing gourami), <i>Osphronemus goramy</i> (giant gourami), <i>Puntius gonionotus</i> (silver barb)	
Livestock–fish polyculture		
Giant freshwater prawn culture systems		
Rice–prawn rotation (prawn during flood season); integrated rice–prawn; pond and pen monoculture	<i>Macrobrachium rosenbergii</i>	An Giang, Can Tho, Ben Tre, Dong Thap
Mariculture systems		
Floating raft culture of oysters	<i>Crassostrea gigas</i>	
Cage mariculture of marine finfish	<i>Panulirus</i> spp. (spiny lobster), <i>Epinephelus</i> spp. (grouper), <i>Lates calcarifer</i> (seabass), <i>Seriola dumerilli</i> (yellowtail), <i>Parargyrops edita</i> (sea bream), <i>Lutjanus</i> spp. (snapper), <i>Hippocampus</i> sp. (seahorse), <i>Pinctada maxima</i> and <i>P. martensii</i> (pearl oyster)	Kien Giang

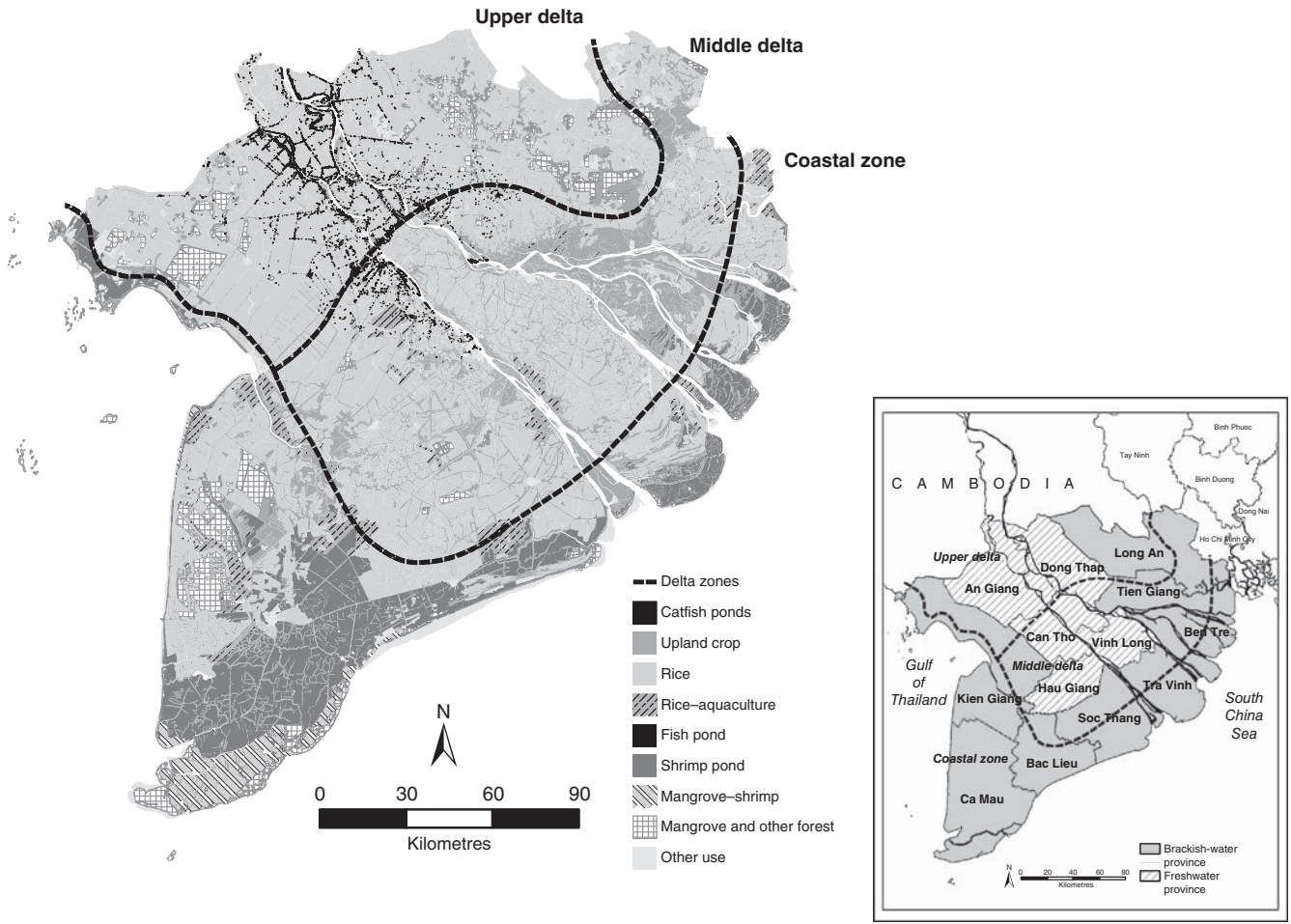


Fig. 9.1. Land use in the Mekong Delta of Vietnam, 2007 (from The Sub-National Institute for Agricultural Planning and Projection (Sub-NIAPP), Vietnam).

need to be protected by raised dykes. With the Vietnamese government's relaxation of land zoning for catfish production in 2002, farms have expanded towards the coast to take advantage of the stronger tidal movement to lower water-pumping costs. Catfish farming is now found in the coastal provinces of Soc Trang and Ben Tre provinces, as far downstream as the water salinity conditions are tolerable to the riverine catfish.

9.3 Climate Change and its Implications on the Aquaculture Industry in the Mekong Delta

As shown in Table 9.2 for the Mekong Delta, the magnitudes of long-term impacts of

anthropogenic climate change on weather and sea events are highly uncertain and are estimated based on plausible scenarios of future socio-economic development that influence greenhouse gas emissions, and consequently the earth's ecophysical responses. Nevertheless, the trends are clear that the Mekong Delta will experience: (i) temperature increases at rates that will appreciate more markedly beyond 2050; (ii) drier dry seasons and wetter rainy seasons; and (iii) SLR that will increase ingress of sea water particularly to parts of the delta that are not already protected.

These climatic and sea-level changes have direct and indirect impacts on aquaculture in the delta. Aquaculture ponds are dependent on water supply from rivers and canals rather than directly from rainfall;

Table 9.2. Comparison of projected changes in environmental variables under moderate and high emission climate change scenarios^a for the Mekong Delta of Vietnam by 2050 and 2100 (relative to the 1980–1999 period).

Change in impacted variable	Moderate emission (B2)		High emission (A2)		Remarks
	By 2050	By 2100	By 2050	By 2100	
Annual mean temperature (°C)					
Marchand <i>et al.</i> , 2011	1.0	2.0	2.0	4.0	
MONRE, 2009	1.0	2.0	1.0	2.6	
Dry season rainfall (%)					
Marchand <i>et al.</i> , 2011	0 to –10	–5 to –15	–10 to –20	–20 to –40	Period considered: November–April
MONRE, 2009	–7.5	–14.3	–7.2	–18.2	Period considered: March–May
Wet season rainfall (%)					
Marchand <i>et al.</i> , 2011	0–5	5–10	10–20	10–30	Period considered: May–October
MONRE, 2009	0.9	1.6	0.8	2.1	Period considered: June–August
Sea-level rise (cm)					
Marchand <i>et al.</i> , 2011	20 to 30	30–50	40–60	100–200	High emission scenario used is
MONRE, 2009	30	75	33	100	A1F1 instead of A2
Increase in salinity intrusion					
Marchand <i>et al.</i> , 2011	slight	moderate	moderate	dramatic	
Low flow of the Mekong ^b (%)					
Marchand <i>et al.</i> , 2011	5 to –5	5 to –15	–10 to –30	–30 to –60	Dry season flow: November–April
Hoanh <i>et al.</i> , 2010	40		42		Low flow season: December–May
High flow of the Mekong (%)					
Marchand <i>et al.</i> , 2011	no change	10	0–10	20–50	Wet season flow: May–October
Hoanh <i>et al.</i> , 2010	–3.3		1.4		High low season: June–August

^aThe emission scenarios identified in the Special Reports on Emission Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC, 2000).

^bThis large discrepancy of projected low flows, from reduced to increased volumes, stems from different model assumptions and reflects the great uncertainty in future scenarios for river flow and discharge into the Mekong Delta, which are influenced by climate change impacts as well as by upstream development of irrigation and hydropower schemes.

hence, changes in hydrological flows and regimes of the delta are expected to be the most significant aspect of climate change impact to affect the aquaculture sector. These changes are influenced not only directly by weather changes, especially rainfall patterns, but also by changes in sea level and by upstream hydropower and irrigation development affecting seasonal flow of the Mekong River into the delta (Hoanh *et al.*, 2010). These changes have large impacts on the availability of water resources, flood events, particularly in the upper delta, and water quality, particularly intrusion of sea water into the coastal zone.

SLR accompanying global warming will result in ingress of sea water further up the branches of the Mekong within the delta, which can exacerbate the accumulation of flood waters from upstream river discharge during the high-flow season and thus aggravate flooding in the upper delta. Figure 9.2 shows the projected increase in maximum flood levels during the rainy season for a 50 cm SLR scenario,³ superimposed with locations of catfish pond areas in each province.

The greatest increments in flooding depth are projected to occur in An Giang, Dong Thap and Can Tho provinces, which

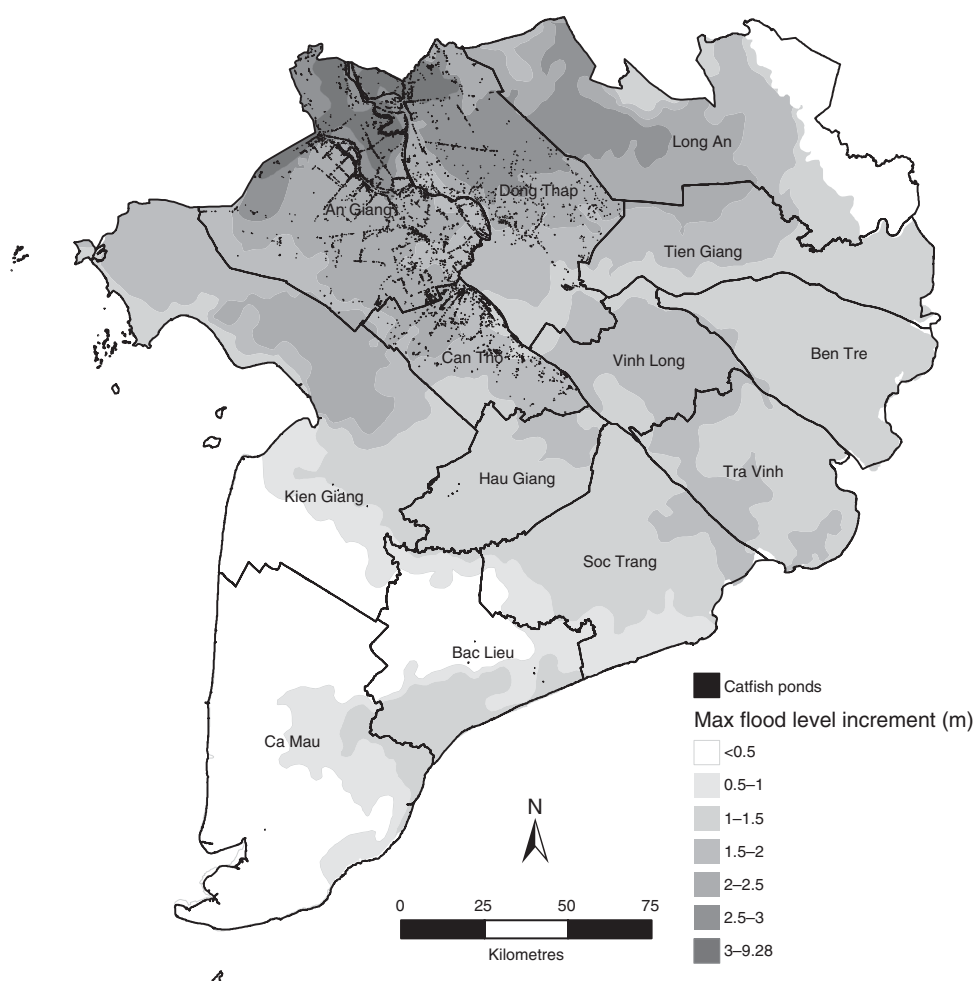


Fig. 9.2. Increment of maximum flood level during the rainy season for a 50-cm SLR scenario, with location of catfish farms in the Mekong Delta of Vietnam (from SIWRP, 2009).

have the largest concentrations of catfish farms in the delta. Catfish ponds would need further protection from seasonal floods. This could be achieved by farmers raising their pond dykes or by benefiting from public initiatives to boost flood-protection measures.

Figure 9.3 shows where increments in maximum water salinity under the 50-cm SLR scenario are projected to occur during the dry season, assuming no additions or enhancements to the existing infrastructure to control salinity intrusion into the delta

(SIWRP, 2009). From GIS analysis (Kam *et al.*, 2012), an estimated 180,000 ha (or 55%) of the shrimp-farming area will experience salinity increments of up to 2 parts per thousand (ppt), and another 45,000 ha (or 11%) will be subjected to salinity increments greater than 2 ppt in the dry season. A further 190,000 ha presently in rice and rice-aquaculture areas are likely to experience increased salinity (above the 4 ppt threshold for rice) during the dry season, thereby providing an opportunity for expansion of brackish-water aquaculture in these areas.

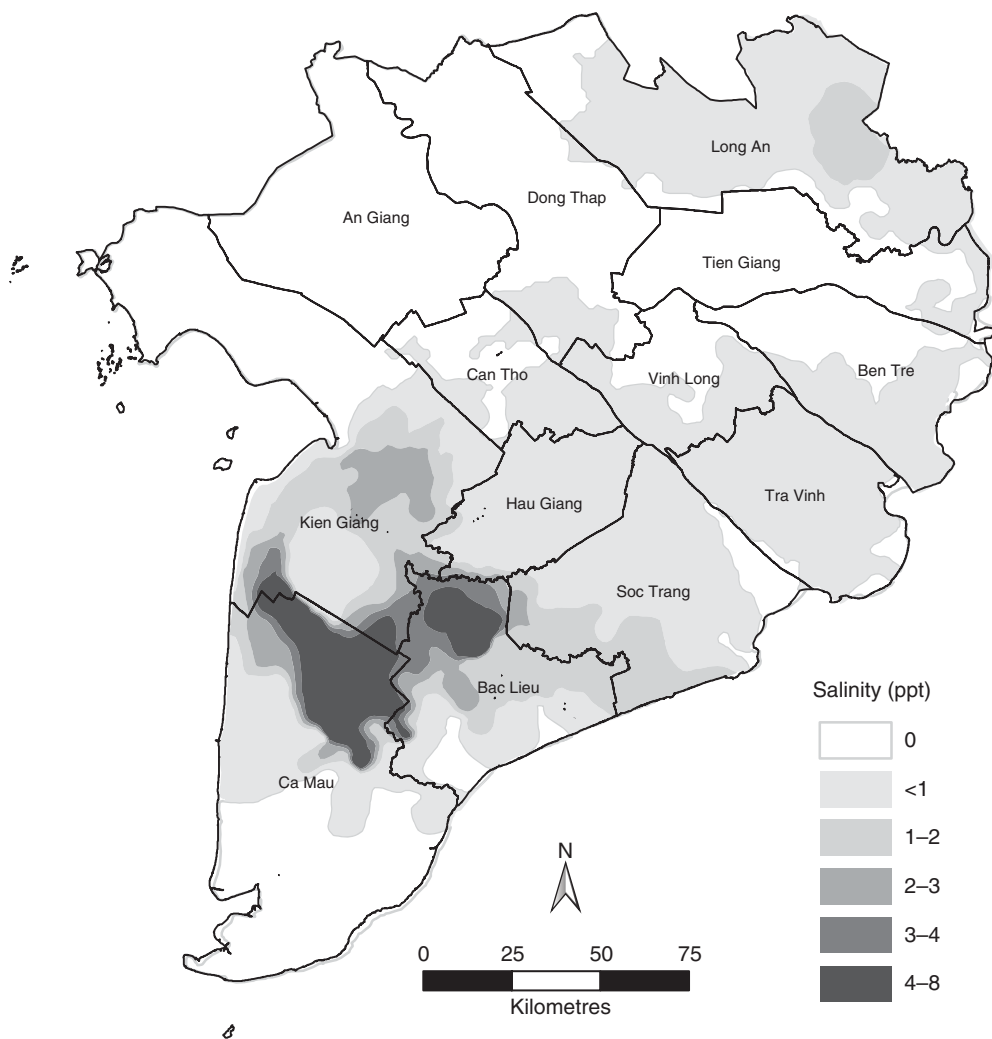


Fig. 9.3. Increment of maximum salinity intrusion during the dry season for the 50-cm SLR scenario in the Mekong Delta of Vietnam (from SIWRP, 2009).

Table 9.3 summarizes the specific impacts of climate change on shrimp and catfish aquaculture in the Mekong Delta, where farmers would have to make adjustments to their farm operations. The associated costs would be taken into account in the economic analysis of autonomous adaptation that is reported in the next section.

9.4 Economic Analysis of Autonomous Adaptation for Shrimp and Catfish Farms

The approach taken in the economic analysis of farm-level autonomous adaptation for shrimp and catfish farms (Kam *et al.*, 2012) involved conducting a farm-level

cost-benefit analysis (CBA) for freshwater catfish and brackish-water shrimp in the Mekong River Delta under climate change (CC) with autonomous adaptation and non-climate change (NCC) scenarios. Four pond-based aquaculture production systems were considered: brackish-water shrimp culture at improved extensive and semi-intensive/intensive scales, and freshwater catfish culture in the inland and the coastal provinces. The analysis was done for two time-periods, from 2010 to 2020 (where projections of climate change impacts on input costs and price changes could be made with relative confidence) and from 2021 to 2050 (where projections become more uncertain).

The production budgets for catfish and shrimp operations in the Mekong Delta from past sample surveys conducted by Sinh

Table 9.3. Sensitivity of cultured catfish and shrimp to expected changes in environmental variables due to climate change.

Climate change impacts	Effect on aquaculture organisms
Temperature rise	Expected increased range within tolerance limits; ^a stress and mortality less likely Enhanced growth rates and feed conversion (metabolic rate) increases oxygen demand and need for aeration Increased decomposition rate of organic detritus in the water reduces oxygen levels and worsens water quality and invasiveness and virulence of bacteria (Dalvia <i>et al.</i> , 2009) and increases need for more frequent water exchange, hence greater water demand with adverse effect on water quality of discharge from ponds Air-breathing catfish (Browman and Kramer, 1985) are better able to withstand low levels of dissolved oxygen than shrimp, which require more aeration
Drier dry season	Higher evaporation rates from ponds increase the need for replenishing with fresh water, also in shrimp ponds to reduce salinity build-up, hence more pumping and electricity use
Wetter wet season	Tendency for greater prevalence of infection of catfish in the rainy season (Thuy <i>et al.</i> , 2010), hence the need and greater costs for disease prevention and control
Increased flooding	Higher risk of loss of fish if ponds overflow, and hence financial loss
Sea-level rise	Increased tidal reach further aggravates inland flooding
Increased salinity intrusion	Increased salinity levels further up the Mekong branches beyond the tolerance limit of river catfish has direct adverse effect on catfish farming in coastal provinces Seasonal salinity increases do not affect shrimp survival rates if kept within the range of 10–35 ppt; higher salinity can retard growth Increased salinity-affected areas in the coastal zone provide expansion opportunities for brackish-water aquaculture

^aThe range of temperature that supports normal growth of *Penaeus monodon* is between 28°C and 33°C (Duong, 2006); *Pangasius* spp. perform well in water temperatures ranging between 22°C and 26°C (from http://www.fao.org/fishery/culturedspecies/Pangasius_hypophthalmus/en (accessed 31 March 2013)).

(2008) were compiled and used as the basis for estimating the baseline (2010) costs and benefits for farm operations. Benefits from farm operations were measured by gross income, and costs comprised fixed and variable farm operation costs. Given the limited sample sizes of the 2008 survey – 131 inland catfish farms, 60 coastal catfish farms, 50 extensive/improved extensive shrimp farms and 50 intensive/semi-intensive shrimp farms – the production data provided were aggregated and averaged over all farm sizes. The averaged estimates would not represent the diversity of farm characteristics such as location, socio-economic circumstances and access to technology and financing, which would influence economic performance of catfish and shrimp farming.

An expert elicitation approach was used to gather local experts' opinions on the impacts of climate change and other drivers of change on variable costs such as land price, feed use and seed use of the four studied aquaculture systems over the past 10 years and in the next 10 years (2010–2020). The 13 stakeholders consulted comprised shrimp and catfish farmers, provincial aquaculture staff and local university researchers specializing in aquaculture. In consultation with the selected 13 stakeholders, drivers of change affecting shrimp and catfish production costs were grouped into four categories: technical, market, pond environment and climate change. The stakeholders provided their perceptions of how the likely effects of climate change parameters on shrimp and catfish culture (listed in Table 9.3) would impact on operating costs (the focus was on variable inputs such as land, feed and seed uses). While expert elicitation may be considered an acceptable approach in the absence of predictive models on the actual impacts of climate change on fish performance and yields (Moss and Schneider, 2000), estimates based on fish growth models and projected yield changes would reduce the uncertainty surrounding the results.

Farm-level costs and benefits were analysed under scenarios of CC with autonomous adaptation (the CC scenario), and with no climate change (the NCC scenario). Under the CC scenario, the full value of input costs

was used. For the NCC scenario, the proportion of costs attributed to CC impacts was omitted. After obtaining the annual net benefits for the analysis period the net present values (NPV) of the CC and NCC scenarios were then compared. The results of the 2010–2020 period are described here as an illustration of economic analysis of the costs of autonomous adaptation at farm level for catfish and shrimp farming.

It is to be noted that the analysis was based on the assumption of linear increase in farm-gate prices for catfish and shrimp. Future market changes were not included in the computation of net benefits, which are highly sensitive to the farm-gate price of fish and shrimp. Similarly, technological advances may impact cost structures, and international trade policies can change demand for Vietnam's aquaculture products. Given the large uncertainty over the interaction of seafood market demand, input prices and costs in the future, these results should be interpreted as the outcome that would exist only if the input price and cost situations assumed in the estimations prevail.

9.4.1 Base production budgets

Tables 9.4 and 9.5 summarize the estimated baseline costs and benefits for catfish and shrimp farming operations, respectively.

Feed constitutes the largest cost in aquaculture production, accounting for 82% and 84% of the variable costs for inland and coastal catfish farms (Table 9.4) and 53% and 66% of variable costs for semi-intensive/intensive and improved extensive shrimp farms (Table 9.5), respectively. Seed and biochemicals account for the next largest costs for both catfish and shrimp production, with biochemicals taking up a high 11% of the variable costs in the semi-intensive/intensive shrimp system. On current trends, catfish farming in general faces a bleak future because gross revenues are not able to keep pace with the past and expected increase in input costs (especially land, feed and seed costs) even in the absence of CC impacts. Only the most efficient and

Table 9.4. Base production budget for inland and coastal catfish farms (costs in Vietnam dollars, VND) (from Sinh, 2008).

Input million ha ⁻¹ crop ⁻¹)	Inland (n= 131)	Coastal (n=60)
Gross income	4868.9	3738.1
Total costs	4616.8	3644.7
Total fixed costs	20.9	28.3
– Depreciation of ponds	11.6	17.15
– Depreciation of machinery	7.17	8.15
– Land taxes	2.13	3.0
Total variable costs	4596.1	3616.4
– Pond preparation	23.6	27.2
– Seed	329.1	263.7
– Feed	3772.5	3051.2
– Chemicals and drugs	205.4	152.4
– Dyke upgrades	11.0	4.6
– Fuel and electricity	48.7	7.7
– Harvest and transportation	28.8	25.4
– Labour	39.2	44.7
– Interest on loans	127.4	33.9
– Miscellaneous	10.4	5.6
Net income	252.1	93.4

Table 9.5. Base production budget for improved extensive (IE) and semi-intensive/intensive (SII) shrimp farms (from Sinh, 2008).

Input (VND million ha ⁻¹ crop ⁻¹)	SII (n=50)	IE (n=50)
Gross income	431.1	65.9
Total costs	193.3	28.8
Total fixed costs	13.53	2.94
– Depreciation of ponds	7.58	1.79
– Depreciation of machinery	4.6	0.85
– Land taxes	1.35	0.30
Total variable costs	179.77	25.86
– Pond preparation	8.09	2.2
– Seed	9.35	3.13
– Feed	119.0	13.7
– Chemicals and drugs	21.0	1.88
– Dyke upgrades	3.05	0.31
– Fuel and electricity	8.63	1.37
– Harvest and transportation	1.61	0.10
– Labour	6.11	1.45
– Interest on loans	1.41	1.14
– Miscellaneous	1.43	0.58
Net income	237.8	37.1

adaptable farmers will survive such a squeeze on farming margins, which are currently in the range of 3–5%. Many catfish farmers, particularly those operating at small scale, might soon find it unprofitable to remain in the sector and will be forced to

leave the industry, which will result in industry consolidation in the hands of large-scale stakeholders vertically integrated. This trend has already been observed in the delta in recent years. For example, in An Giang province the number of small catfish farms

(<500m²) declined from 3200 in 2004 to only 547 in 2009 (Little and Murray, n.d.).

Current trends are more favourable for shrimp farming, with margins of 123% and 129% for semi-intensive/intensive and improved extensive farms, respectively (Table 9.5).

9.4.2 Costs of autonomous adaptation

The results from Kam *et al.* (2012) for the 2010–2020 period are described here as an illustration of economic analysis of the costs of autonomous adaptation at farm level for catfish and shrimp farming. As shown in Fig. 9.4, net income remains positive until 2018 and only until 2015 for inland catfish and coastal catfish farms, respectively, under the NCC scenario. Under the CC scenario, the additional costs of adapting to climate change will intensify the squeeze on the slim profit margins of catfish farms, thus hastening the onset of net losses. Catfish farms in the coastal provinces will be particularly affected adversely by increased salinity intrusion up the rivers reducing freshwater supply to the ponds. Comparison of NPVs for the NCC and CC scenarios suggests that responding to climate change over this period would result in a decrease in discounted net income of VND4.7bn ha⁻¹ for coastal catfish farms over the 2010–2020 period.

In comparison, shrimp farms manage to produce positive net benefits for a longer period than catfish operators due to lower total costs relative to gross income. As shown in Fig. 9.5, net incomes remain positive over the 2010–2020 period but responding to climate change leads to a more rapid decrease of net income. Comparison of NPVs for the NCC and CC scenarios suggest that responding to climate change over this period would result in decreases in discounted net income of VND51.6 million ha⁻¹ for improved extensive shrimp farming and VND403.7 million ha⁻¹ for semi-intensive and intensive shrimp farming.

The economic analyses show that autonomous adaptation of aquaculture to CC increases farm-level operation costs. Catfish farmers already operate at the brink of economic viability given increases in input costs and reduction in prices of marketed products in recent years. Climate change is just an additional driver to decrease even further the expected profitability of catfish culture. Shrimp farmers overall are able to bear the cost of adaptation over a longer time frame than catfish farmers. This is because outlooks for shrimp markets are in better condition compared to those for catfish. Furthermore, the shrimp industry is more spread out, involving much larger geographical areas and a larger number of stakeholders. It is more mature and less capitalized and so it is projected that the shrimp

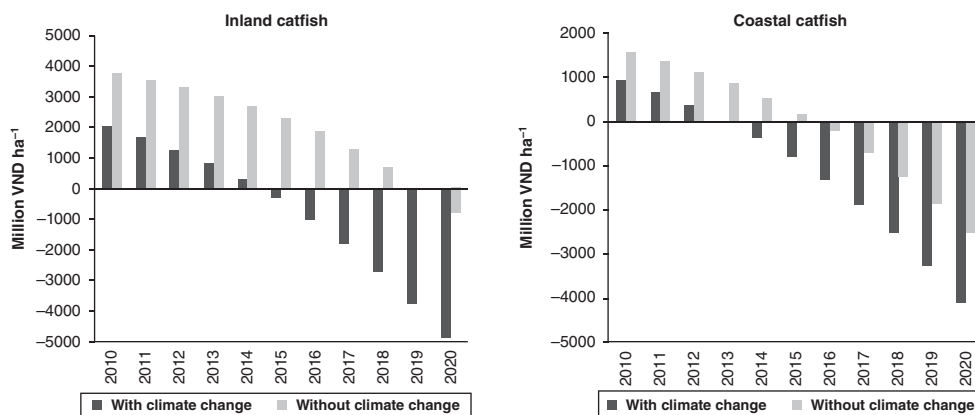


Fig. 9.4. Net farm income from catfish under climate change and no climate change scenarios for the period 2010–2020.

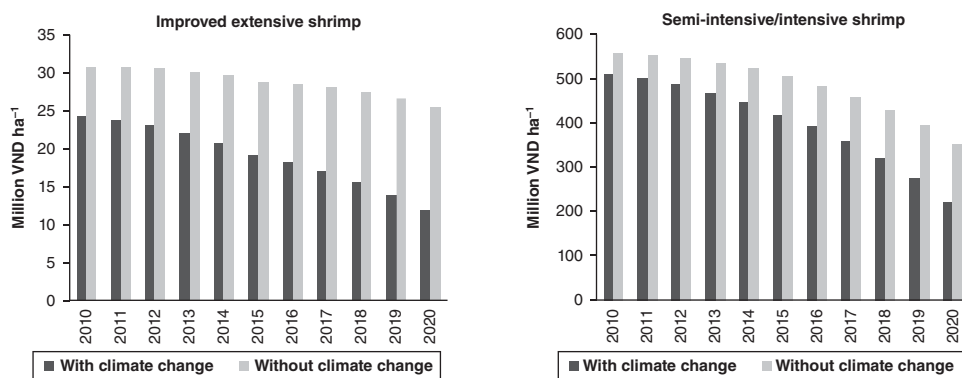


Fig. 9.5. Net farm income from shrimp under climate change and no climate change scenarios for the period 2010–2020.

industry can remain profitable for longer than catfish under CC scenarios. Despite its lower profitability compared with the semi-intensive/intensive system, improved extensive shrimp culture is more sustainable, both environmentally and economically, especially for small-scale farmers.

9.5 Planned Adaptation: The Case of Water Resources Management

Considering the economic importance of the aquaculture industry for Vietnam, government-funded planned adaptation measures that can partially offset certain farm-level costs of autonomous adaptation would bring relief to farmers, especially those already operating with narrow profit margins. In particular, planned adaptation measures relating to water resources management in the delta have direct implications on the aquaculture sector. A recent water resources development plan for the Mekong Delta (Fig. 9.6) takes account of its anticipated agricultural development scenario for this decade and the next, with a vision to 2050 (SIWRP, 2010).

Catfish farms in the inland provinces will mainly benefit from improved flood protection measures that are broadly targeted for rice and other agricultural crops in the upper and middle delta zones. The study by Kam *et al.* (2012) illustrates the case where

public investment on constructing flood protection infrastructure in the upper delta would ease the financial burden on catfish farmers to raise their pond dykes. Estimates of the farm-level costs for upgrading catfish pond dykes were scaled up to the industry level by taking account of the prevailing area extents of the two catfish production systems and estimates of the extents to which these areas would be affected by successive increments in flooding depth resulting from SLR, based on a GIS analysis of the map in Fig. 9.2.

Figure 9.7 depicts the escalating costs for raising pond dykes of catfish farms in response to incremental increases in flooding depth for the 2010–2020 period at the industry level for the delta, which amounts to an estimated US\$17.6 million of autonomous adaptation cost over this 10-year period. Considering that the catfish export value from the Mekong Delta for just the year 2012 was US\$1.7bn, and that the Mekong Delta accounts for 98% of Vietnam's catfish export value,⁴ this cost is nominal but would help defray the operational costs of individual catfish farmers and increase the profitability of farms that are already operating at slim profit margins.

Water management is more complex in the coastal zone where water provides a range of goods in terms of fresh- and brackish-water resources for agriculture, aquaculture, and urban and industrial uses, as well as ecosystem services that support

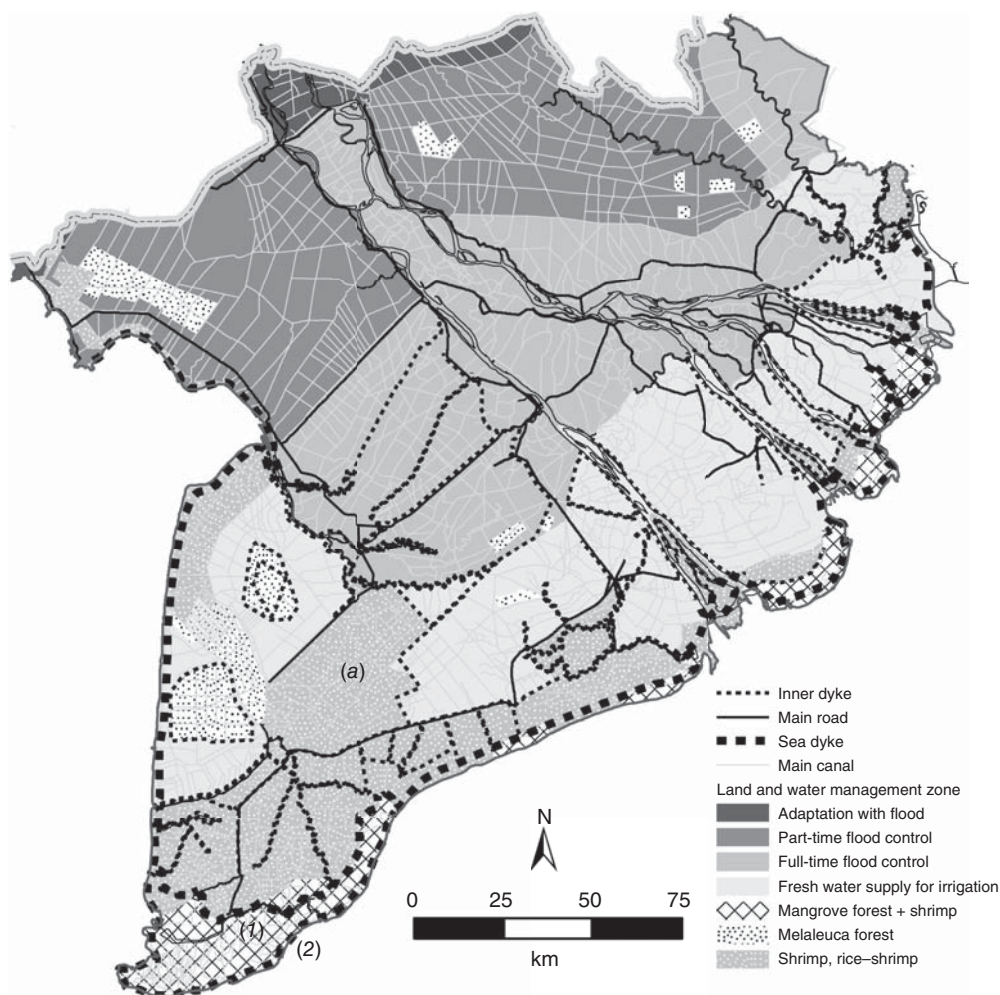


Fig. 9.6. Water resources planning for the Mekong Delta (from SIWRP, 2010).

coastal fisheries and maintain a variety of wetland ecosystems including mangrove forests. Adaptation strategies, including planned adaptation, can bring about potential synergies as well as conflicts among different economic sectors. Achieving a delicate balance that ensures equitable access and efficient sharing of the water resources to meet the needs of the various sectors requires non-structural measures besides structural ones appropriately implemented at field to community and regional levels (Nhan *et al.*, 2007).

The prospects for brackish-water aquaculture in the coastal zone depend on the

extent and configuration of water control infrastructure planned for the future. The existing shrimp and shrimp–rice areas inland of the national highway linking Bac Lieu and Ca Mau cities will benefit from plans to continue partial control of salinity intrusion into the coastal zone by judicious operation of sluices and temporary dams that allow intake of sea water in the dry season and flushing out of saline and pollutant-laden water in the rainy season (Hoanh *et al.*, 2009). This operational control of salinity intrusion is itself a nonstructural adaptive mechanism that provides flexibility for managing the water resources to meet

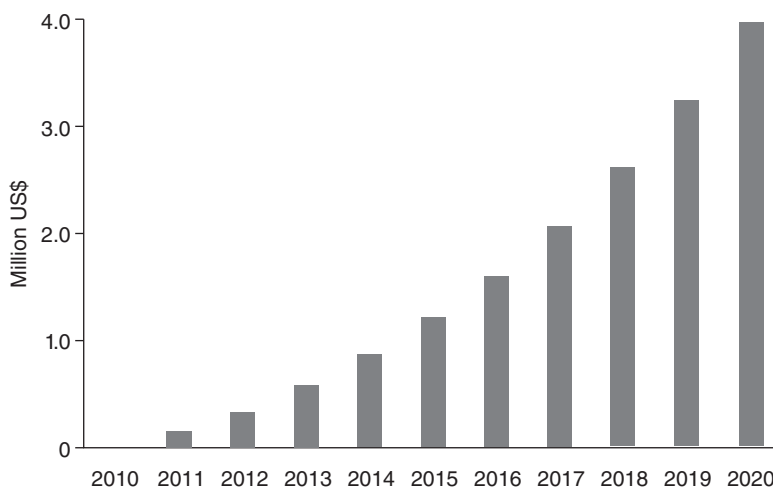


Fig. 9.7. Autonomous adaptation cost for upgrading dykes of inland catfish ponds at industry level for the Mekong Delta, 2010–2020 (from Kam *et al.*, 2012).

agriculture and aquaculture requirements as physical (including climatic) and socio-economic (including markets) conditions change. The projected increase in dry-season salinity in these areas beyond the tolerance limits for rice would, in fact, shift land use in favour of brackish-water aquaculture expansion. On the other hand, structural measures, such as construction of sea embankments for protection of coastal communities and agricultural land from storm surges and full prevention of land salinization, would mean removing the brackish-water aquaculture area marked (a) in Fig. 9.6 out of production. Such structural measures will also have negative impacts on fisheries in the coastal zone by preventing the natural movement of food-fish species up the rivers and canal networks.

The water resources planning map (Fig. 9.6) suggests two possible alignments for the sea dyke for coastal protection in the south-western tip of Ca Mau peninsula. The alignment marked (1) in Fig. 9.6, favoured by the Ca Mau provincial authorities, is along the shoreline outside of the remaining largest area of mangroves in the delta. The alignment marked (2), as suggested by the Southern Institute for Water Resources Planning (SIWRP), lies inland of this mangrove area. The ecological integrity of

the mangrove area is less likely to be compromised with the latter alignment as its ecosystem health is dependent on natural tidal inundation and shoreline accretion. The mangroves and the accreting mudflats constitute wetlands that support a rich diversity of aquatic organisms that have food and economic potential, including molluscs (cockles) and crustaceans (mangrove crabs). Mangrove–aquaculture systems are more environmentally friendly, taking advantage of natural flushing and nutrient supply, and its products can be targeted at elevated prices at niche markets. For example, in 2010 more than 1000 organic shrimp farms with a total of 6200 ha within the mangroves have been certified by Naturland (Samson, 2010). A healthy and expanding mangrove strip also provides a protective buffer against coastal events and storm surges.

9.6 Aquaculture-specific Adaptations

Besides adaptation plans on water resources management that can benefit aquaculture in the Mekong Delta, there are also other possible response strategies to CC impacts that are specific to the aquaculture sector.

A number of such strategies pertain to better farm management practices such as improving feed conversion ratios and the use of local alternatives of feed materials (to be achieved through research) into feed formulation that reduce feed costs as well as the carbon footprint of formulated feeds (Bunting *et al.*, 2009). Technical improvements such as specific pathogen-free shrimp brood-stock technology will help reduce disease risks that might increase with CC impacts (De Silva and Soto, 2009). A combination of selective breeding programmes and changes in farming practices would enable the farming of catfish strains that can better tolerate higher levels of salinity. Many of these strategies would increase farm profit margins, thereby helping underwrite the costs of adaptation. While the adoption of improved stocks and the modification of farming practices will be the task of those responsible for managing aquaculture operations, planned adaptation options such as genetics selection and breeding programmes fall within the mandate of the government. These strategies may be regarded as 'no-regret' strategies in that they contribute towards building a general resilience beyond specific adaptation to CC, and are therefore not overly dependent on detailed quantification of its specific impacts (Heltberg *et al.*, 2009).

Another strategy that applies particularly to export-oriented aquaculture production would be to transfer the cost of adaptation across the value chain, thereby increasing the margins accruing to farmers rather than to export processing companies and retailers in importing countries. This could happen either on the initiative of actors higher up the value chain as a market response to maintain the supply to meet growth in demand, or by government intervention, community- or civil society-driven measures in recognition of the importance of maintaining the welfare of the large number of small farmers and transferring benefits from a globally integrated production system to the rural communities in the delta.

In the long-term, reducing the high dependence on shrimp and catfish culture and diversifying into more ecologically oriented production systems can also hedge the aquaculture industry against the increasing risks and uncertainties brought about by CC. The export-oriented aquaculture industry in the South-east Asian region, based on the industrial monoculture model, is highly dynamic and volatile, and the economic risks are high (Szuster, 2003), not to mention the high environmental and social costs that producer countries have to bear.

Unlike the staple crops and livestock, there is actually a high diversity of aquatic species and production systems that can be, and are being, practised, as indicated in Table 9.1. These range from purely aquaculture systems to integrated production within rice and mangrove environments. The integrated systems among those listed in Table 9.1 are cited by Costa-Pierce (2010) as good examples of the ecological aquaculture paradigm promoted by FAO (Soto *et al.*, 2008), which calls for responsible aquaculture that takes account of its interactions and influences on the surrounding natural and social environments for better sustainability, equity and resilience.

Because these production systems fit into different agro-ecologies, an aquaculture sector that possesses such diversity would have greater adaptability to changes in hydrological conditions that result from CC impacts. On the other hand, water resources management strategies that accommodate the range of saline, brackish water and freshwater environments will provide the opportunities for this diversity of aquaculture systems to be further developed and improved, thereby keeping future options open for viable alternatives to the industrial-style monoculture systems that dominate the sector today. It is also imperative that future aquaculture planning, particularly for integrated systems that are ecologically more sound, should be done in conjunction with irrigation and water resources enhancement and within the broader context of the delta's development and response to climate change.

9.7 Conclusions

Assessing the economic cost of the impacts of CC and adaptation at the farm level in aquaculture remain uncharted research areas. Given the constraints of conventional cost-benefit analysis adopted by Kam *et al.* (2012), a more thorough integrated assessment of the economics of planned adaptation is needed to examine trade-offs in costs and benefits of adaptation options among sectors which include the aquaculture industry. Modelling of the impact of CC on growth, production and yield of cultured species is urgently needed to enable better estimation of projected farm yields under different CC scenarios and management responses.

All economic studies of CC adaptation are subject to substantial uncertainty surrounding the impacts of future CC, changes in input and output of commodity prices, and changes in production technologies and other factors. Indeed, for the Mekong Delta, the future outlook is riddled with uncertainties: in terms of extremities of climate change, of developments that will occur in the upstream Mekong, and of the economic developments that will happen within the delta. These uncertainties impinge upon the aquaculture sector, which is presently dominated by export-oriented monoculture production of shrimp and catfish. Economic analyses of these two major aquaculture production systems suggest that the costs of farmers' autonomous adaptation to CC impacts will further erode their farm profits and render the less-efficient farms economically unviable much sooner, *ceteris paribus*. Part of the autonomous adaptation costs can be offset to some extent by planned adaptation measures undertaken with public investment, as illustrated by the flood mitigation measures defraying catfish farmers' costs for raising pond dykes in the flood-affected upper and middle delta zones.

Structural responses to CC impacts incur high levels of investments into infrastructure development and are less flexible for adjustments in the face of uncertain future outcomes of climate and other global changes. Combinations with non-structural

measures for more nimble adaptation strategies would be necessary for long-term resilience of the aquaculture sector. The diversity of aquaculture production systems provides opportunities for fitting into different agro-ecologies and lends itself to a high degree of transformability of the sector in the face of changing hydrological conditions brought about by CC.

The impetus for diversification needs to be driven by policy that is integral to the country's development plan for fisheries and aquaculture, which must include the broader sustainability issues facing the sector. In the same way that Vietnam has a proven capacity to build an aquaculture industry of global significance, the potential exists for the country to take a lead in the transition from an industrial monoculture phase of aquaculture development to a more diversified, integrated and ecologically sensitive phase that promotes innovation and efficiency by incorporating and not externalizing social and environmental costs. The Mekong Delta, with its vast and diverse land and water resources, and faced with the challenges of CC impacts, presents the opportunity to make this transition.

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Notes

- ¹ Based on data obtained from the Vietnam Association of Seafood Exporters and Producers: http://seafood.vasep.com.vn/statistics/50_121/814/1/seafood-export-statistics.htm (accessed 7 November 2015).
- ² These areas were originally planned in the 1990s to be fully protected from intrusion of sea water

for expanding rice intensification by constructing a series of sluices. However, rapid expansion of shrimp farming since the early 2000s and soil acidification from exposure of acid sulfate soils in the area rendered these areas less suited for intensive rice cultivation. A government policy reversal enabled these non-structural adjustments to accommodate both shrimp and rice farming.

³ A 50-cm SLR is anticipated by 2100 under the moderate emission scenario and would be surpassed by 2050 under the high emission scenario (Table 8.2).

⁴ General Statistical Office of Vietnam, http://www.gso.gov.vn/default_en.aspx?tabid=469&idmid=3 (accessed 29 March 2013).

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