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Impact of saline intrusion and adaptation options on rice- and fish-farming households in the Mekong Delta of Vietnam

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Abstract

Saline intrusion is threatening rice- and fish-farming households in the Mekong Delta of Vietnam. This study was conducted, based on interviews with 390 rice- and fish-farming households in An Giang, Can Tho, and Soc Trang—upstream, midstream, and downstream provinces, respectively—in the Mekong Delta, Vietnam. The results revealed that saltwater intensively intruded inland during the dry season and seriously affected rice- and fish-farming households. Not only the productivity of rice and fish was affected, but also household income, and the quality of natural resources and environment deteriorated. The fish-farming households faced the most serious effects and had fewer adaptation options compared to households undertaking farming with rice and integrated rice- and fish-farming. Households in all groups have developed adaptation options following the increasing degree of salinity, including: (1) changing their agricultural activity calendar, (2) using tolerant rice varieties and fish species, (3) changing cropping patterns and farming practices, (4) applying integrated production models, and (5) diversifying non-farming activities.

Introduction

Saline intrusion has affected the backbone economy and harmed millions of people living in the Mekong Delta of Vietnam (Tuan, 2012), especially during January and April every year (Thanh & Toan, 2009). Saline intrusion significantly damages agricultural land and productivity, drinking water, ecosystem services, and biodiversity, and reduces the country's gross domestic product due to the loss of household livelihood (Kuenzer & Renaud, 2012). Over two million hectares of agricultural land area are strongly impacted by saline intrusion. The intrusion threatens the national food security, affecting the livelihoods of millions of local people, and impacting economic development (Hanh & Furukawa, 2007; Tri, 2012). The consequences of saline intrusion not only increase the pressure on people's livelihoods, but also lead to unstable food security issues. Agriculture, natural fisheries, and aquaculture are at risk. This ongoing trend has significantly impacted millions of people who are thriving on rice and fish production (Kuenzer & Renaud, 2012).

Adaptation plays an important role in mitigation of the impacts of saline intrusion. It is a process by which communities seek to confront the consequences of saline intrusion and enhance their resilience (Adger, 2006; Smit & Wandel, 2006). Adaptation to saline intrusion in the Mekong Delta of Vietnam has been approached through various means, depending on the geographical location in the Delta, the level of development of communities, and household capacity (Kuenzer & Renaud, 2012). The National Target Program to Respond to Climate Change was approved in 2009 as an important master plan on saline intrusion adaptation for the overall sustainable development of Vietnam (Ministry of Natural Resources and Environment, 2009). However, households may not have the right attitude towards adaptation because most people in midstream and upstream areas of the Mekong Delta have not yet thoroughly realized the impacts of saline intrusion. Therefore, this research targeted rice- and fish-farming

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households in order to analyze how these households are affected by saline intrusion and how they use adaptation options to tackle the problems caused by saline intrusion.

Methods

Study Areas

The study was carried out in the Mekong Delta of Vietnam. Targeted households were those living in three different parts of the Mekong Delta of Vietnam: upstream, midstream and downstream provinces (Figure 1).

An Giang, a representative of upstream provinces, has not yet been affected by the present saline intrusion. In 2012, this province produced 3,843,600 t of paddy rice, accounting for 9 percent of the country's entire production (DARD of An Giang, 2014). The Mekong Delta of Vietnam, even as far upstream as An Giang province, would be impacted by higher annual floods caused by higher sea levels, even if saltwater did not reach the back of the Delta. Can Tho, located in the midstream area, has been impacted by saline intrusion since 2002 (DARD of Can Tho, 2014). This province has high potential for agricultural and aquacultural development, but suffers from saline intrusion during the dry season. In 2010, over 1,000 ha of agricultural land were impacted by drought and saltwater intrusion (Thanh & Toan, 2009). Soc Trang, a representative of downstream coastal provinces, has been heavily affected by saline intrusion since the 1970s (DARD of Soc Trang, 2014). This province not only has high potential in aquaculture and agricultural production, but also suffers severely from the impacts of saline intrusion. It has a coastline of 72 km with low-level land (less than 2 m above sea level), resulting in frequent sea-floods during high tide periods. In May 2010, saltwater covered about two-thirds of the province and traveled about 70 km up the rivers from the sea—a rise of 10 km in the last five years—causing the loss of over 2,000 ha of rice production due to drought and saline intrusion (Thanh & Toan, 2009).

Household Sampling and Sampled Size

One district was sampled within each of the three selected provinces, with two communes within a sampled district being chosen. A household survey was carried out during November 2014-April 2015 at the six locations representing different parts of the Mekong Delta. In each commune, households involved in rice- and fish-farming were randomly sampled. Sample sizes were calculated using the formula of Yamane (1973); 390 samples were derived for household interviews as shown in Table 1.

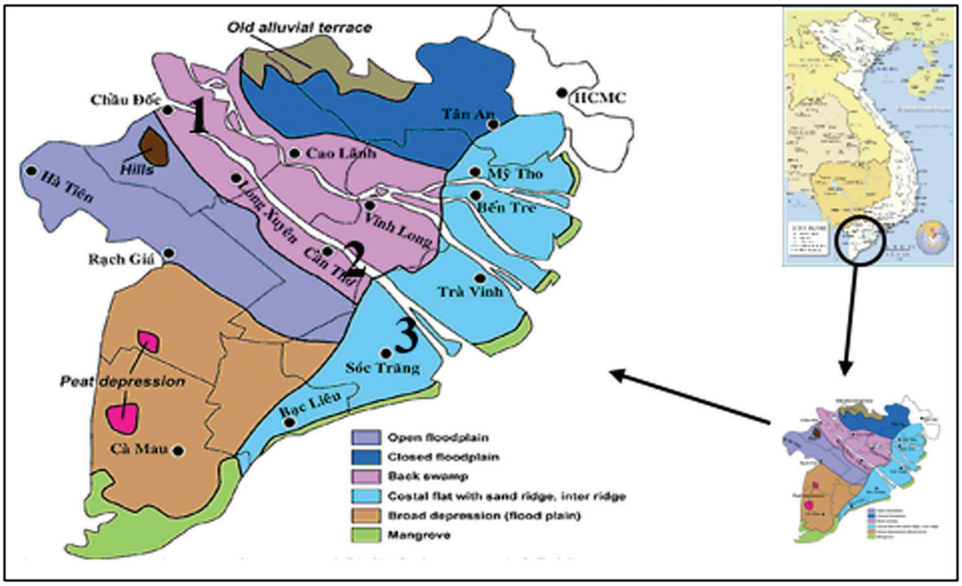

Figure 1 Map of the Mekong Delta of Vietnam and locations of the study areas (1 = An Giang, 2 = Can Tho, 3 = Soc Trang)
Source: http://www.mekongcruises.net/halong-images/news/img2/mekongdeltamap2.gif

Table 1 Numbers of total and sampled households

Province	Sampled district	Selected commune	Total number of households	Number of sampled households
An Giang	An Phu	Vinh Hau	1,561	43
		Phuoc Hung	2,871	79
Can Tho	Cai Rang	Phu Thu	2,711	74
		Hung Thanh	2,186	60
Soc Trang	Long Phu	Long Phu	2,638	72
		Dai Ngai	2,229	62

Household Interviews

A structured questionnaire was designed, approved by the Central Institutional Review Board of Mahidol University, pretested, and used as a tool for the household interviews. Key questions included household background information, awareness and understanding of saline intrusion affecting rice- and fish-farming activities and livelihoods, impacts of saline intrusion on rice and fish, and how rice- and fish-farming households were responding and adapting to the adverse effects of saline intrusion.

Collection and Analysis of Water and Soil Samples

In total, 390 water samples were collected from irrigation channels and 390 soil samples were collected at each of the interviewed households, and analyzed. The electrical conductivity (EC) was measured using a conductivity meter and salinity was estimated (Australian Wine Research Institute, 2010; Department of Environment and Primary Industries, 1999). The results were used to reaffirm the degree of impacts of saline intrusion on rice- and fish-farming.

Results and Discussion

Situation of Saline Intrusion in the Past and Present

According to DARD of Soc Trang province, the saline intrusion into the Mekong Delta of Vietnam was first observed in the 1970s, infiltrating 7 km up the Mekong River Delta with salinity > 4 ppt. During the past four decades, the saltwater has reached about 60–70 km up river (Southern Institute for Water Resource Planning, 2014). The saline intrusion in the Mekong Delta is influenced by the mainstream reverse flow and tide (Tri, 2012). The tide is a main factor affecting the ratio of flow distribution in the Mekong Delta of Vietnam. During the dry season, when the Mekong River freshwater flow decreases, seawater flows up through the network of waterways and directly affects 60–70 km of the estuaries of the Mekong River Delta (Tuan, 2012). The saline intrusion level increases significantly in late March and levels off until mid-May. The extent of saline intrusion along the Mekong River of Vietnam is shown in Figure 2. The saline intrusion reduces, shortening the salinity distance accordingly when the rainy season commences in early June.

The highest common salinity levels at the research sites were recorded mostly in late March and early April. It was evident that the salinity level went up again in early May before it leveled off in June. The saline intrusion progress was indicated by the curves representing the variability in the salinity level recorded at each research site along the Mekong River Delta of Vietnam. The salinity measured at the three research sites along the Mekong River Delta of Vietnam showed significantly high levels downstream. Specifically, in April 2014 at Soc Trang, the highest water salinity recorded was 18.2 ppt in the estuary zone (Figure 3).

Impact of Saline Intrusion on Soil and Water

The intrusion of saltwater affects soil quality and water quality. The analytical data from the 390 soil samples and 390 water samples collected from the three research sites in April 2015 confirmed that both the soil and water were salt contaminated (Table 2). Soc Trang and Can Tho, (downstream and midstream provinces, respectively) were affected by saltwater during the dry season. In Soc Trang province, the soil and water samples had various salinity levels. The average soil salinity was 0.9 ppt (max = 7.1 ppt) and the average water salinity was 0.8 ppt (max = 2.6 ppt). In Can Tho province, the average soil salinity was 0.3 ppt (max = 3.4 ppt), but no salinity was detected in water samples perhaps because of the exchange between the saltwater and freshwater during the tidal rise and deposition of salts inland. Despite low average soil salinity in Can Tho, it should be noted that the maximum soil salinity was still very high. In An Giang, the upstream province, no salinity was detected in any of the soil and water samples. These results confirmed that the water sourced for irrigation was salt-contaminated in midstream and downstream locations in the Mekong Delta. The saline intrusion was most severe in Soc Trang province, the downstream area, which in 2015 had a maximum soil salinity of 7.1 ppt and a maximum water salinity of 2.6 ppt. However, saline intrusion was different in Can Tho province, the midstream area, where the maximum soil salinity was 3.4 ppt in 2014, but salinity in water was zero at the same time. Soil salinity was higher than water salinity in both Can Tho and Soc Trang provinces due to salt contamination by land through the irrigation of crops.

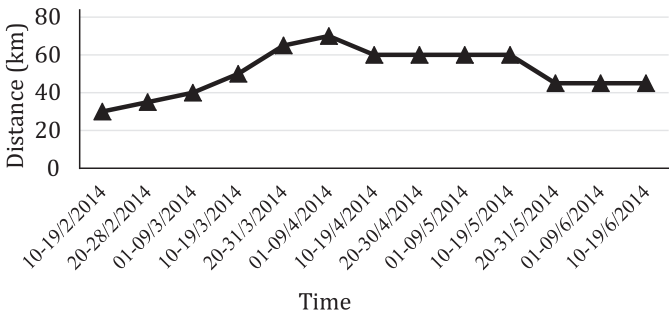

Figure 2 Saltwater infiltration inland during the dry season of 2014
Source: Southern Institute for Water Resource Planning (2014)

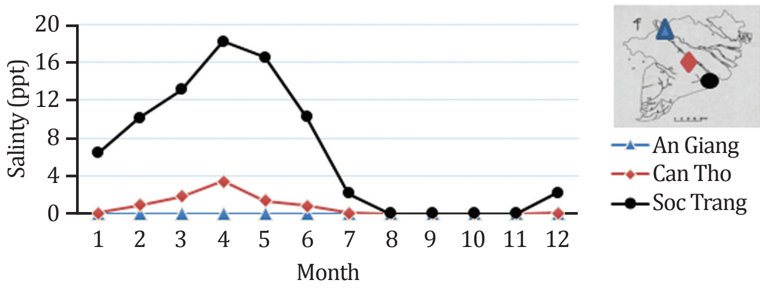

Figure 3 Average monthly salinity progress in the Mekong Delta of Vietnam in 2014
Source: Southern Institute for Water Resource Planning (2014)

Table 2 Soil and water salinity results (n = 390) at research sites (2015)

Province	Soil salinity (ppt)				Water salinity (ppt)			
	Mean	Min	Max	SD	Mean	Min	Max	SD
An Giang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Can Tho	0.3	0.0	3.4	0.6	0.0	0.0	0.0	0.0
Soc Trang	0.9	0.0	7.1	1.3	0.8	0.0	2.6	0.7

Impacts of Saline Intrusion on Farmlands

Approximately 1.7 million ha of rice land and 0.4 million ha of fish farm area in the Mekong Delta of Vietnam were affected by saline intrusion from salinity levels between 1.5 and 8.2 ppt (Southern Institute for Water Resource Planning, 2014). The results from the household survey in 2015 indicated that in Soc Trang, the downstream province, over 90 percent of the rice farming area, 85 percent of the fish farming area, and 43 percent of the integrated rice- and fish-farming area were affected by saline intrusion. In Can Tho province, the areas affected by saline intrusion accounted for 9 percent of the rice farming area, 43 percent of the fish farming area, and 19 percent of the integrated rice- and fish-farming area. while in An Giang, the upstream province, saline intrusion was not detected in either rice paddies or fish areas. In addition, in Can Tho and Soc Trang provinces, 14.6 percent of the surveyed households stated that they had converted parts of their farmlands (0.46 ha/household) from rice- and fish-farming into shrimp farming. In Soc Trang province, 31.8 percent of the surveyed households left their farmlands fallow throughout the duration of saline intrusion impacts. Although the agricultural production areas were protected by a system of dykes and sluice gates, saltwater could infiltrate the farmland when the sluice gates were opened for irrigation.

Impacts of Saline Intrusion on Yields of Rice and Fish

Yield losses for rice and fish varied among the three research sites. Correlation between the level of salinity and the yields of rice and fish indicated the influence of different levels of salinity on those yields. The rice and fish yields in Soc Trang were significantly affected by levels of salinity (Table 3). If salinity increased one level (from non to very low, very low to low, low to high, or high to very high), the rice yield would decrease 0.528 t/ha. If the salinity increased one level, the fish yield would decrease 1.37 t/ha. In Can Tho province, although the level of salinity was not correlated with yields of rice or fish, the yield of rice and fish still decreased 0.138 t/ha and 0.008 t/ha, respectively, when the salinity increased one level (Table 4).

Table 3 Correlation between salinity level and the yield of rice and fish in Soc Trang province

Variable	Estimated coefficient (β)	S.E	t-stat	Sig.
Constant	5.741**	1.637	3.506	.002
Rice yield in Soc Trang (t/ha)	- 0.528*	0.209	- 2.533	.020
Fish yield in Soc Trang (t/ha)	- 1.370*	0.146	- 2.541	.019

(*n* = 134 interviewed households in Soc Trang; R squared = 0.39)
(* = significant at 95% confidence level; ** = significant at 99% confidence level)

Table 4 Correlation between salinity level and the yield of rice and fish in Can Tho province

Variable	Estimated coefficient (β)	S.E	t stat	Sig.
Constant	3.275	1.586	2.065	.131
Rice yield in Can Tho (t/ha)	- 0.138	0.110	- 1.259	.297
Fish yield in Can Tho (t/ha)	- 0.008	0.078	- 0.117	.915

(*n* = 134 interviewed households in Can Tho; R squared = 0.49)

Impacts of Saline Intrusion on Household Income

The impacts of saline intrusion on the household income from rice- and freshwater-fish-farming differed among the three research sites. The percentage income loss of households from fish farming was higher in all three research sites (Table 5). Soc Trang province had the highest loss of household income (42%) for sampled fish households, compared to An Giang (4%) and Can Tho (31%) provinces. The average household loss in income from rice farming and fish farming was highest in Soc Trang province, with the loss from rice farming, fish farming, and integrated rice- and fish-farming being 31, 42, and 20 percent, respectively. The income from fish farming was higher compared to rice farming and to integrated rice- and fish-farming at all three research sites. Integrated rice- and fish-farming was affected the least by saline intrusion whereas fish farming was affected most severely because monoculture fish farming was more vulnerable to this problem than other farming activities.

Table 5 Average loss in household income between 2008 and 2014

Farming activity	Household income (USD/ha/year)					
	An Giang		Can Tho		Soc Trang	
	2008	2014	2008	2014	2008	2014
Rice cultivation	1,850	1,850	1,850	1,400	1,800	1,250
Fish farming	56,000	54,000	56,000	38,500	55,000	32,000
Integrated rice and fish	9,000	9,000	11,650	9,500	11,500	9,200
Percentage of household income loss						
Rice cultivation		-		24%		31%
Fish farming		4%		31%		42%
Integrated rice and fish		-		18%		20%

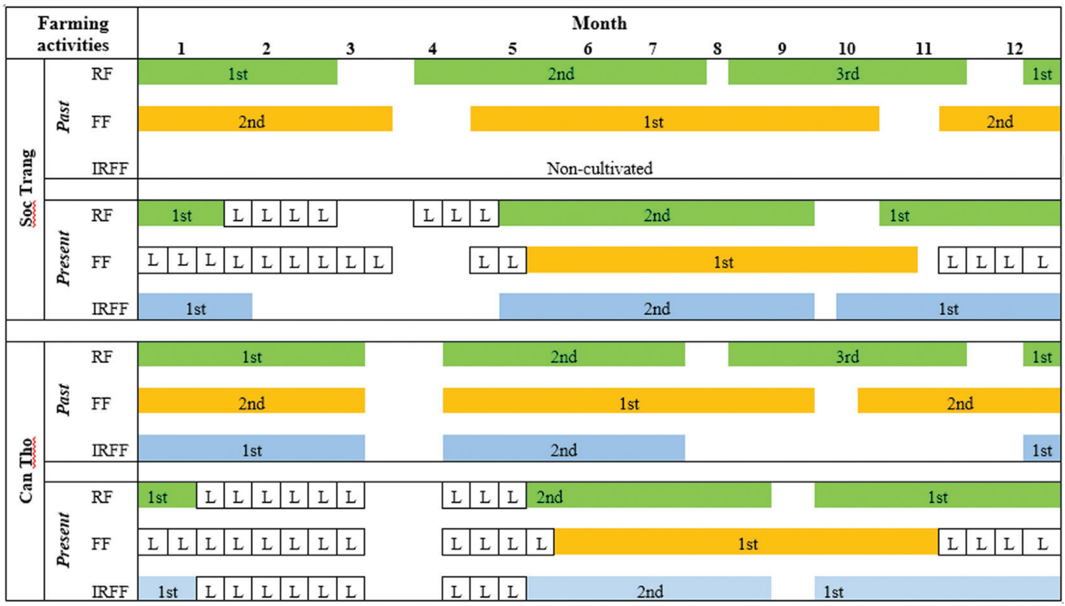

Figure 4 Cropping calendar changes due to saline intrusion in Soc Trang and Can Tho during the past five years
(RF = rice farming; FF = fish farming; IRFF = integrated rice- and fish-farming)
(L = loss; 1st = first crop; 2nd = second crop; 3rd = third crop)

Impacts of Saline Intrusion on Farming Practices

The impacts of saline intrusion caused changes in farming practices and the cropping calendar, rice varieties, and fish species, (Figure 4) leading to an increase in production costs. Over 60 percent of households involved in rice- and fish-farming in Soc Trang and Can Tho provinces changed their cropping calendar due to the adverse impact of saline intrusion during March–May; for example, the timing for growing and harvesting rice compared to growing rice in high elevation areas where the soils were not affected by salinity. An Giang province respondents had not changed their cropping calendar for rice- and fish-farming during the past five years, while households in Can Tho and Soc Trang provinces had changed their cropping calendar compared to five years ago under the impact of saline intrusion, so that their present rice- and fish-farming began one month later in order to avoid the period of strongest saline intrusion. In Soc Trang province, most of the surveyed households (> 70%) had been reduced to just one rice crop/year and one fish crop/year for the past five years. Most households in Can Tho province rarely cultivated three rice crops/year and had reduced rice- and fish-farming from 2012 levels due to progressive salinity in the dry season. The results showed that saline intrusion had reduced rice- and fish-farming activities in midstream and downstream areas.

Compared to the 2008 baseline when there was less impact and the normal cropping calendar was still maintained, surveyed households had not only changed their cropping calendar, but also had changed land use, especially in Soc Trang and Can Tho provinces (Table 6).

The results from the household surveys demonstrated that rice farming households reduced the use of land during saline intrusion (29.6 ha in Soc Trang province and 40.4 ha in Can Tho province). Fish farming areas decreased 13.1 ha in Soc Trang province and 0.9 ha in Can Tho province, when compared to the 2008 baseline. Integrated rice- and fish-farming areas decreased in Soc Trang province (1 ha) and An Giang province (1.7 ha), but in Can Tho province it increased by 0.5 ha.

Table 6 Land use change caused by saline intrusion on rice- and fish-farming between 2008 and 2014

Farming activity	Land use (ha)					
	2008			2014		
	An Giang	Can Tho	Soc Trang	An Giang	Can Tho	Soc Trang
Rice cultivation	163.4	79.8	286.1	163.9	39.4	256.5
Fish farming	10.3	1.8	21.6	11.5	0.9	8.5
Integrated rice and fish	9.3	0.0	2.2	7.6	0.5	1.2

Adaptation Options to Saline Intrusion for Rice and Fish Farming Household

Rice- and fish-farming households at the three research sites had few options to cope with the saline intrusion problem. Adaptation involved: changing the cropping calendar and cropping patterns, introducing new rice varieties, production models and farming techniques, and leaving land fallow or changing the land use (Table 7).

These changes not only contributed to stable household production activity, but also ensured household income. Changes in farming techniques were less common than other ways to deal with saline intrusion; however, many surveyed households had changed their traditional farming techniques. Specifically, 23.9 percent of surveyed households indicated that they would find new jobs by emigration to other places and some surveyed households said they would leave their farm when they could find a good job. These adaptation methods differed among the three research sites because of household capacity, household location, and government policy support. Faced with saline intrusion, adaptation options were chosen in accordance with government policies and household adaptive capacity. Based on the salinity level, households of different groups acted different ways to deal with the saline intrusion impact.

Households involved in rice farming relied on two or three crops of rice monoculture per year. Different levels of salinity led to different adaptation options (Table 8).

In areas with very low salinity levels, changing the cropping calendar was the prioritized option in order to continue cultivation. Changing farming practices was also an option for areas with low salinity levels. Changing cropping patterns was implemented at the moderate salinity level in order to avoid cropping during the period when the salinity increased. In addition, using tolerant rice varieties was also recommended as an option to maintain stable productivity and income was applied as an adaptation option for rice farming households. Sugarcane and shrimp farming were promoted for farming activities because they could be adapted to highly saline conditions. Non-farming activities such as seeking new jobs elsewhere were the last option for the areas contaminated with high salinity. Fish farming households cultivated freshwater fish as a monoculture such as Tra fish (*Pangasius hypophtha*) and Snakehead fish (*Chana maculata*), changing from a rice monoculture because of the higher profit gained. Fish farming households had fewer adaptation strategies in response to the different levels of saline intrusion than did rice farming households (Table 9) because freshwater fish were most sensitive to salinity damage.

Table 7 Adaptation options to cope with saline intrusion problem at the three research sites

Adaptation option	Household (%)			Mean (%)
	An Giang	Can Tho	Soc Trang	
Change in cropping calendar	5.6	13.4	17.2	12.1
Change in production models	4.7	11.8	7.6	8.0
Freshwater stored	39.5	24.5	35.3	33.1
Change in cropping patterns	6.9	21.6	9.3	12.6
Change in varieties	11.6	17.6	6.2	11.8
Change in farming techniques	0.0	2.0	9.2	3.7
Built sluice gate	18.6	9.8	1.6	10.0
Change in land use/left fallow	41.5	38.1	35.9	38.5
Migrate to find new jobs elsewhere	14.2	23.6	34.1	23.9

Table 8 Adaptation options of rice farming households to different levels of salinity

Level	Impact	Opportunities	Adaptation Option
Very low (< 1 ppt)	- Salinity affected - Soil and water quality reduced; salt-contaminated land		- Changing part of farming practices
Low (1–2 ppt)	- Salinity strongly affected, salt-contaminated land - Loss of productivity - Less rainfall, drought, freshwater shortage	- Develop integrated production model	- Changing part of farming practices, crop patterns, cropping calendar
Moderate (> 2–3 ppt)	- Salinity stronger effect, more disease, freshwater shortage - Damage to productivity	- Use of new rice varieties, develop shrimp farming, new plant farming (sugarcane)	- Change all farming practices - Apply tolerant varieties, use of short-term rice varieties, new production model
High (> 3–4 ppt)	- Completely change fresh water ecosystem	- Develop saltwater system farming	- Migration/seek new jobs elsewhere - Completely change production model - Reduce rice crop
Very high (> 4 ppt)	- Soil and water quality reduced; salt-contaminated land	- Develop saltwater system farming	- Non-farming activities, shrimp farming

Table 9 Adaptation options of fish farming households to different levels of salinity

Level	Impact	Opportunity	Adaptation Option
Very low (< 1 ppt)	- Low salinity effects	- None	- Changing part of farming practices
Low (1–2 ppt)	- Water quality reduced, salt-contaminated land	- Use new fish species	- Changing part of farming practices - Use tolerant fish species
Moderate (> 2–3 ppt)	- Strong salinity effect, salt-contaminated land - Yield loss, more disease, freshwater shortage	- Develop brackish water fish	- Change all farming practices - Reduce fish crop, apply new production model
High (> 3–4 ppt)	- Strong salinity effect - Productivity/yield damage	- Brackish water fish and shrimp farming	- Migration to seek jobs elsewhere - Completely change production model
Very high (> 4 ppt)	- Completely change fresh water ecosystem	- Saltwater system farming	- Shrimp farming - Non-farming activities

Changing farming practices was the best solution as new salt-tolerant fish species were introduced to the areas with low and moderate levels of salinity. Decreasing saline intrusion throughout the duration was a solution for freshwater fish production at a moderate salinity level. Shrimp or brackish water fish species were promoted as adaptation options for fish farmers who were considering changing. Non-farming activities such as seeking new jobs elsewhere was the last option for the areas contaminated with high levels of salinity.

The integrated rice- and fish-farming group changed from rice or fish monoculture to integrated rice- and fish-farming in order to obtain higher profit and reduce the risks if the price of either rice or fish was reduced. They had fewer options for adaptation if the salinity level increased.

Conclusion

Fish farming was the most vulnerable to the adverse impacts of saline intrusion, compared to rice farming or integrated rice- and fish-farming with regard to loss of household income and low production capacity. Rice- and fish-farming households developed adaptation options depending upon the degree of impact, household capacity, and support from government policies. There were many adaptation options that were applied in three research sites, including: (1) changing the cropping calendar, (2) using salt-tolerant rice varieties and fish species, (3) changing farming practices, (4) applying integrated production models, and (5) diversifying for non-farming activities such as migration and off-farm jobs.

Conflict of Interest

There is no conflict of interest.

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