Pertanika J. Soc. Sci. & Hum. 28 (2): 1553 - 1566 (2020)

PERTANIKA JOURNALS

SOCIAL SCIENCES & HUMANITIES

Journal homepage: http://www.pertanika.upm.edu.my/

Adapting to Saline Intrusion: Empirical Insights from Two Coastal Areas in the Vietnamese Mekong Delta

Van Huynh Thanh Pham[1, 2], Rudi Febriamansyah[3], Afrizal[4] and Thong Anh Tran[5, 6, 7]*

[1]*Graduate School, Andalas University, Padang 25163, West Sumatra, Indonesia*
[2]*Faculty of Agriculture and Natural Resources, An Giang University, VNU-HCM, 18 Ung Van Khiem, Long Xuyen City, An Giang, 90000, Vietnam*
[3]*Faculty of Agriculture, Andalas University, Padang 25163, West Sumatra, Indonesia*
[4]*Faculty of Social and Political Sciences, Andalas University, Padang 25163, West Sumatra, Indonesia*
[5]*Asia Research Institute, National University of Singapore, AS8, Level 7, 10 Kent Ridge Crescent 119260, Singapore*
[6]*Fenner School of Environment and Society, College of Science, The Australian National University, Canberra, ACT 2600, Australia*
[7]*Research Center for Rural Development, An Giang University, VNU-HCM, 18 Ung Van Khiem, Long Xuyen City, An Giang, 90000, Vietnam*

ABSTRACT

Saline intrusion (SI) is increasing at an accelerating rate in the coastal zones of the Vietnamese Mekong Delta (VMD). This challenges various crop production practices in these areas. Using ecological and social approaches, this paper aims to explore farmers' perceptions of SI occurring in Tra Vinh and Kien Giang provinces, and their adaptation measures to deal with the situation. A mixed-method approach was used, including in-depth interviews, focus group discussions, and household surveys. The results demonstrated that farmers have implemented various adaptation measures in tackling SI impacts. High market demand for shrimp also contributed to farmers' decisions in shifting farming practices. The study underscores the important role of the integrated shrimp-rice system as a more comparatively sustainable model to the intensive shrimp culture in the face of SI. Qualitative analysis revealed water conflicts occurring in mixed rice and shrimp farming areas driven by the poor performance of combined irrigation and drainage systems together with the undefined water demarcation zones between rice and shrimp farmers. The paper provides better insights into how farmers' adaptation

ARTICLE INFO

Article history:
Received: 03 May 2019
Accepted: 20 January 2020
Published: 26 June 2020

E-mail addresses:
phtvan@gmail.com (Van Huynh Thanh Pham)
r_febriamansyah@agr.unand.ac.id (Rudi Febriamansyah)
afrizal@soc.unand.ac.id (Afrizal)
thong.tran@nus.edu.sg (Thong Anh Tran)
* Corresponding author

ISSN: 0128-7702
e-ISSN 2231-8534

strategies could facilitate decision-making processes with regard to water management and adaptation policies in the coastal areas. It calls for local governments' attention to modifying water infrastructure to better address water-related issues.

Keywords: Adaptation, climate change, farmer perception, intensive shrimp farming, saline intrusion, shrimp-rice system, Vietnamese Mekong Delta

INTRODUCTION

The Mekong River (4,400 kilometers in length) originates from the Tibetan Plateau and flows through Southern China, Myanmar, Thailand, Laos, Cambodia and the Vietnamese Mekong Delta (VMD) before it empties into the East Sea. Historically, the physical formation of the delta is linked closely to changes in sea level and hydrological effects of the Mekong River. The last 7,000 years has witnessed the expansion of the region owing to continuous alluvial deposition from the Mekong River (Climate Change-Agriculture and Food Security-Southeast Asia [CCAFSSEA], 2016). The delta was sparsely populated before the arrivals of the early Vietnamese migrants about 300 years ago (Le et al., 2007).

The hydrological systems of the VMD are characterized by flooding in the upper part, which is closely linked to water dynamics in the coastal areas (i.e. lower part) of the delta (Käkönen, 2008; Ministry of Agriculture and Rural Development [MARD], 2017a). Concerning this, SI occurs when there are no adequate river discharge[1] flows to estuaries (Vietnam Institute of Meteorology - Hydrology and Environment [VIMHE], 2010), thus leading to saline intrusion into the mainland. The long coastline (700 km) of the delta with a flat and low elevation (e.g., 0.5-1.2m above the mean sea level) and the density of canal and drainage systems (around 4 km in length/km^2) provide enabling conditions for saltwater to intrude deeply and extensively into both sides of the region (the West Sea and the East Sea) (Estellès et al., 2012; Käkönen, 2008; MARD, 2017b; Vo, 2012).

Recent reports indicated that, following natural regulations, SI occurred frequently between 1977-1996[2]. It was first recognized in 1998 as a natural hazard (Dang et al., 2007). Evidence suggests that SI correlates with environmental change and human development processes occurring not only in the VMD but also in the broader geographical scales (e.g., hydropower dam construction and land-use change in the Mekong region) (Dang et al., 2007; Nguyen, 2016a).

Saline intrusion places irrigation-based agriculture and livelihoods of coastal inhabitants at high risks (Institute of Policy and Strategy for Agriculture and Rural Development [IPSARD]), 2016; Nguyen, 2016b; Vo, 2012). Substantial evidence

[1] During the dry season from December to April, the average discharge of the Mekong River is about 6,000 m^3/s (the lowest is about 2,000 m^3/s from March to April). In the wet season, this is much higher, about 25.500m^3/s (Vo, 2012).

[2] SI has been monitored and recorded since the national unification in 1975, assisted by 75 gauging stations installed across the delta (Le, 2017).

illustrates negative impacts on coastal livelihoods over the past few decades (Renaud et al., 2015; To et al., 2003; Tran & Le, 2011; Tran et al., 2019a, 2019b). There have been multiple efforts made by both local government and farmers in responding to salinity impacts on the ground. While local governments built salinity control projects to tackle the issue across the coastal areas, farmers proactively engaged in the adaptation process by intensely shifting their farming practices and patterns (IPSARD, 2016; Nguyen, 2016c; Tran et al., 2019a). The compounding impacts climate change, upstream hydropower development, and local infrastructural development processes have made SI increasingly complex and uncertain, threatening traditional livelihoods of the majority of coastal farming inhabitants (Käkönen, 2008; Tran et al., 2019b; Vo, 2012).

Adaptation to adverse impacts of SI is therefore critically important, especially to local farmers. By definition, adaptation is a human response to environmental changes, which refers to adjustments in ecological, social, or economic systems responding to actual or expected climatic stimuli and their effects or impacts (Smit & Pilifosova, 2003). Adaptation is highly contextual and action-specific (Agrawal et al., 2009; Bowyer et al., 2014; Burton et al., 2006). Rambo (1983) mentioned that understanding of local situations, and to what extent the social-ecological systems contribute to people's adaptation was essential. This is particularly significant in the context of SI in the VMD, where the majority of inhabitants depend on agricultural and aquacultural production as the main means of livelihoods.

While most studies focus on climate-related vulnerabilities and their impacts on the agricultural systems and adaptation options associated with SI at the local level (Joint Assessment Team, 2016; Nguyen, 2016c, 2017; Nguyen et al., 2012; Vo, 2014), there remains little empirical understanding of the ways in which farmers adapt farming practices to fit with environmental change. This study aims to fill this knowledge gap by exploring farmers' adaptation dynamics associated with SI in the two coastal sides of the delta. Equally important, it attempts to understand the historical processes of SI in the study areas, and the ways they shape adaptation responses at the local level.

METHODS

Selection of Research Sites

The coastal zones of the delta are characterized by the mixed diurnal (the west) and semi-diurnal (the east) tidal effects[3] (Nguyen, 2008; Vo, 2012). This has salient impacts on SI, and how it varies accordingly (Southern Institute of Water Resources Research [SIWRR], 2015). According to the Ministry of Natural Resources and Environment (MONRE)'s report (2016), both sides of the delta have been profoundly exposed to salinity over the past few years, which is projected to be more serious in the future.

[3] The tide regime of the Vietnamese East Sea is characterized by semi-diurnal effects (amplitude about 2.5-3.0m), while that of West Sea by diurnal effects (amplitude about 0.8-1.0m).

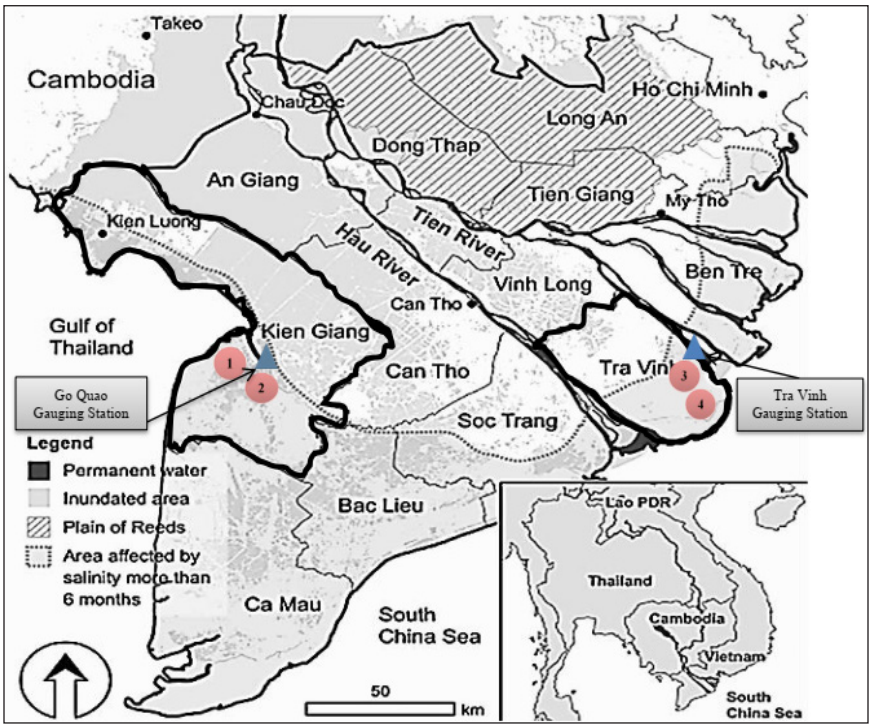

Figure 1. The maps of the VMD and the research sites: (1) Nam Yen commune, (2) Dong Thai commune, An Bien district; (3) Vinh Kim commune and (4) Hiep My Dong commune, Cau Ngang district
Sources: Mekong River Commission (2005, modified from Käkönen (2008))

Severely affected by SI in recent years, An Bien district in Kien Giang province (on the west side) and Cau Ngang district in Tra Vinh province (on the east side) were selected as the research sites. These provinces represent two different geographical zones of the delta, which are respectively influenced by the diurnal (the west) and semi-diurnal (the east) tidal systems (Figure 1). Following transects from seashores to inland zones, one commune adjacent to and one far from the coastlines in each district were selected to explore various impacts of SI. Accordingly, the study sites include Nam Yen and Dong Thai communes in An Bien district; Hiep My Dong and Vinh Kim communes in Cau Ngang district.

Data Collection and Analysis

This study employed the mixed-methods approach, using both qualitative and quantitative methods (Afrizal, 2016; Creswell & Creswell, 2017; Miller et al., 2010). Field data were collected using in-depth interviews, group meetings, and household surveys. Qualitative data included sixteen meetings held with key informants across administrative (communal, district, and provincial) levels and four group meetings in the four communes. These data were gathered to explore such key themes as farmers' perception of SI, farmers' adaptation responses, and environmental conditions of farming systems. Apart from the qualitative data, a household survey

was also administered to 280 households in the research sites (70 households in each commune). Those who have lived in the areas for more than ten years and were directly affected by SI were selected for the survey.

A stratified random sampling approach was applied to recruit participants for the survey (de Vaus, 2002; Walliman, 2006). Questionnaires were tested and revised to several randomly sampled households in the research areas before the surveys were officially administered to selected participants. The fieldwork was conducted from 2017-2018.

Qualitative data were transcribed and categorized into themes for further analysis. Quantitative data was coded and analyzed using descriptive analysis association with trend analysis (e.g., SI trend), farmer's perceptions of SI, and adaptation practices. Data on annual salt concentration levels were calculated into means to indicate the progress of SI over time.

Secondary data from local government reports were also used in the study, including SI situations, monthly data of salinity concentration (from January to April) collected at Go Quao gauging station (about 30 km inland from the West Sea) and Tra Vinh station (about 36 km inland from the East Sea) from 2002 to 2016 together with scientific reports from SIWRR. Analyses of these official documents complement the empirical findings of the study.

FINDINGS AND DISCUSSION

Salinity Situations in the Research Areas

SI occurs on both sides of the delta, but its intensity varies substantially. Data collected from the two gauging stations (Ben Trai and Tra Vinh) from 2002 to 2016 suggested that high levels of salt concentration were recorded on both sides during the dry months (Figure 2). The current climatic conditions suggested that the salinity is more likely to increase in the west.

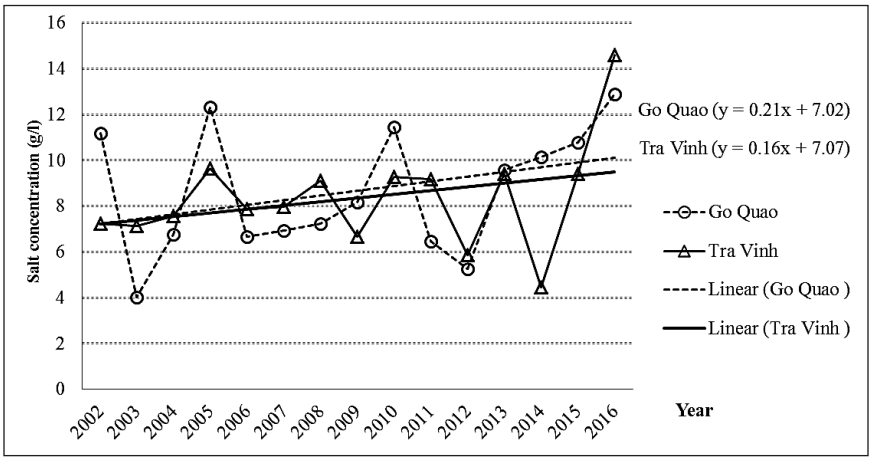

Figure 2. Levels of salt concentration in the research sites from 2002-2016
Source: SIWRR (2015, 2017). Figure created by the first author.

SI has changed across coastal areas over the past few years (SIWRR, 2015). This can be attributed to several factors. For the most part, salinity control projects[4] built in the east help mediate the SI effects (Nguyen & Huynh, 2014; Tran, 2009). This could explain why the intensity of SI in the east is lower than that in the west. As observed by an agricultural officer in An Bien district, SI has become more intense in recent years. This adversely affects the local agricultural production and coastal resource-based livelihoods.

Greater efforts to address the SI have been observed at the institutional level. For instance, the government in Cau Ngang district built a number of major sluices to protect local farming from the SI impacts (H. S. Le, personal communication, December 10, 2017). This study makes an urgent call that both non-structural and structural measures should be simultaneously undertaken to help reduce the SI impacts in the area.

[4] These include control projects in Go Cong, South Mang Thit, Quan Lo Phung Hiep and Ba Lai aimed to control saltwater from encroaching into the agricultural land area of about 926,000 ha and some 650,000 ha devoted to urban and aquacultural areas (Nguyen, 2016a; Tran, 2009; Vo, 2012).

Farmers' Perceptions of SI

Table 1 shows farmers' perceptions of SI. Farmers on both sides of the delta were aware of the change in SI, which had become more complicated in terms of frequency since the year 2000. Some 86.5% of farmers in An Bien perceived that SI affected their farms, while roughly 43.5% in Cau Ngang had a similar view. This could be generally implied that the effects of SI in the west appear to be more recognizable than in the east.

Those who have experienced natural disasters perceive that such events have significant impacts on their lives (Le et al., 2014). This is also reflected in this study. Farmers in An Bien were likely to perceive

Table 1
Farmers' perception of SI (N=280)

SI	An Bien district (%)	Cau Ngang district (%)
Conditions		
Usual	14.9	26.1
Unusual	85.1	73.9
Impacts on agricultural production		
Yes	86.5	43.5
No	13.5	56.5
Level of impact on local livelihoods		
1- Not very serious	2.9	5.7
2- Not serious	11.2	42.6
3- Do not know	2.3	0.0
4- Serious	63.4	50.0
5- Very serious	20.2	1.7

Source: Household surveys (2017-2018)

more impacts of SI than those in Cau Ngang. It could be due to the fact that farmers in the former are not well protected by local salinity control systems which were not fully implemented.

Historical analysis of rural adaptation suggests that the delta plays a key role in sustaining local inhabitants' subsistence livelihoods (CCAFSSEA, 2016; (Estellès et al., 2012). In earlier times, local inhabitants collected available resources (e.g., fish, vegetables) without much intensive labor. The prevailing climate change impacts imply that the delta is no longer a 'delicious' region offered by God (Le, 2017). As SI is getting more complex and uncertain, it is important that farmers need to increase their awareness of environmental change that affects their livelihoods. Because salinity control projects do not sufficiently deal with the impacts of SI (Nguyen & Huynh, 2014; Tran, 2009), farmers themselves in both sides of the delta need to be proactive in their adaptive actions. In this light, it is essential that farmers' and governmental efforts need to be further integrated (Pham et al., 2018). Local farmers' perceptions of the SI should be integrated into the local decision-making processes and the building of salinity control systems to deal with the issue.

Change in Farming and Water Management Practices

Various forms of adaptation have been adopted by farmers on the ground. Driven by increasing SI impacts on both sides of the delta, some farmers shifted from intensive rice production to shrimp farming[5]. This reflected that the land-use change as the result of this new farming pattern was closely linked to the level of salinity encroaching into both sides of the delta. Realizing emergent environmental conditions triggered by SI, most farmers decided to transform their traditional farming systems to ensure that they can better adapt to change (Table 2).

The results indicated that between 1954 and 1990 farming practices in the two study sites were relatively similar. However, since the 1990s there has been much divergence in ways farmers adjusted their farming systems to accommodate environmental changes. For instance, farmers in the Cau Ngang district have changed their farming patterns from rice to shrimp rice and then to intensive shrimp farming systems.

Table 3 presents the difference in farming systems farmers practiced in the two districts. While the majority adopted the extensive shrimp rice systems in An Bien (99.3%), this was not the case in Cau Ngang. Farmers in the latter preferred adopting intensive shrimp farming systems (68.2%).

The variation of shrimp farming patterns in the two areas can be attributed to several factors. First, natural conditions and market are the key factors that drive farmers to

[5] Shrimp cultivation takes two primary forms: (1) extensive (low density) and (2) intensive (high density). The former depends on saltwater available in the dry season, followed by a rice crop in the rainy season. This farming practices comes without or little feed supply with a density of 1-2 shrimp larvae/m^2; the latter includes two or more shrimp crops per year with feed supply and a density of 30-50 shrimp larvae/m^2. Highly intensive shrimp cultivation indicates higher density of shrimp larvae in the pond (around 100-150 larvae/m^2).

Table 2
Timeline of shifting farming systems in the research sites

Time	An Bien district	Cau Ngang district
1954 -1975	High coverage of wild forests (Mangrove forests) Sparse settlements Dominance of one rice crop per year with low yield (1-1.2 ton/ha) Abundant supply of natural aquatic resources in the dry season	
1975 -1990	Increased resident settlements in the coastal areas Conversion of forest areas and abandoned land into cultivated land areas First introduction of double-rice crop systems since 1978 (high-yield varieties) Expansion of the double rice crop systems Decline in aquatic resources	
1990 - 2000	Prevalence of the double-rice crop systems	Introduction of the integrated shrimp rice system since 1994
2000 - 2010	Introduction of shrimp rice system since 2003	Shift from shrimp rice to intensive shrimp farming system in 2000
2010 - Now	Shrimp rice farming practice remains until now	Prevalence of the intensive shrimp farming system Adoption of the highly intensive shrimp farming system since 2017

Source: Group discussions (2017-2018)

Table 3
Farming yystems in An Bien and Cau Ngang districts (N=280)

Farming systems	An Bien district		Cau Ngang district	
	Farm size (ha)	%	Farm size (ha)	%
Shrimp rice farming	1.8 ± 1.2	99.3	1 ± 0.6	24.1
Intensive shrimp farming	-	0.7	0.7 ± 0.7	68.2
Double rice crops	-	-	0.7 ± 0.4	1.9
Others	-	-	0.5 ± 0.3	5.8
Average farm size	1.8 ± 1.2	100	0.9 ± 0.7	100

Source: Household interviews (2017-2018)

change their decisions (Asian Management and Development Institute [AMDI], 2016; Dang et al., 2007). According to an agricultural officer in Hiep My Dong commune, Cau Ngang district, shrimp culture brings relatively better income (T. B. N. Nguyen, personal communication, January 23, 2018). Due to its low price in the market, farmers planted rice for family consumption. Farm size also contributes to the change in farming systems. For integrated shrimp-rice systems, farmlands have to be large enough because about 25-30% of their areas have to be devoted to the trench building for shrimp. It was observed that this system is mainly practiced in the west side of the delta because of its larger farmland areas (Table 1).

The majority of farmers in Cau Ngang district adopted intensive farming systems. It was because these practices could yield greater profits from smaller farm

sizes (Appendix 1). Qualitative analysis suggested that before 2008, farmers largely cultivated black tiger shrimp (*Penaeus monodon*). However, they soon shifted to the culture of white leg shrimp *(Litopenaeus vannamei)* because these species can live in higher density, and their culture period is shorter. The adoption of the intensive shrimp farming system could be seen as a game-changer. It is because farmers, when adopting the intensive shrimp system, hardly switch back to rice farming given the high salt concentration in soil.

Most farmers in An Bien district consider the shrimp rice system as a sustainable model that brings greater income and creates an environment-friendly farming practice (no pesticide used for rice as it is not suitable for the ensuing shrimp crop). This system allows efficient nutrient exchange from the preceding shrimp crop, which provides a rich source of natural fertilizer for the following rice crop. Decayed rice straws left on the field provide an important source of feed for shrimp (AMDI, 2016). Black tiger shrimps (*Penaeus monodon*) are especially dominant because they require less or no feed to be added to the farm. This enabled most farmers (96%) not to switch to intensive shrimp farming as they would face higher risks (e.g., diseases) that could be contagious from adjacent farming zones.

Farmers are found to be flexible in adjusting their farming systems to accommodate local environmental conditions. For instance, when the water is not salty enough, farmers replace black tiger shrimp with freshwater giant prawn (*Macrobrachium rosenbergii*) [6]. Such diversifications (shrimp, rice) allow farmers to deal with the instability of market prices (Pham & Febriamansyah, 2017). Roslina (2018) indicated that most brackish water farmers earn a higher profit than the fresh farmer. So, it is interesting that local farmers have recently switched back to traditional farming systems which exist more than 40 years[7] (AMDI, 2016). This study found that the shrimp rice system could be a sustainable farming system that would provide a better and more stable income for farmers.

Different from counterparts in An Bien, farmers in Cau Ngang district preferred to adopt the intensive shrimp farming system as it brings better income than the integrated shrimp-rice model. However, the former system is subject to high risks (Nguyen & Andrew, 2010). Seeing that shrimp would generate higher profit compared with rice alone, most farmers decided to convert their paddy fields to shrimp ponds. The shift from rice to shrimp was not possible for the poorer rice farmers due to the high capital investment and the cost of shrimp larvae (Tran & Le, 2011).

Qualitative analysis suggested that most farmers in Cau Ngang district earned high profits in the first few years before the shrimp yields started to decline due to diseases, unsuitable weather and chemical pollution

[6] Freshwater giant prawn (*Macrobrachium rosenbergii*) sustains well in the lower salinity level from 4-6g/l, whereas black tiger prawns are more favorable to higher salt level from 15-20g/l.

[7] Before shifting to the double rice crop model, farmers grow rice in the wet season and harvest wild aquatic species in the dry season.

(V. D. Nguyen, personal communication, January 10, 2018). Thirty-nine point four (39.4) % of farmers encountered big losses (Appendix 2). The study found that some farmers switched to other farm-based livelihoods or migrated to the urban areas in search of work.

External factors play a major role in influencing farmers' choices in which farming systems they should invest. This is related to the function of irrigation systems. Both salinity control and irrigation projects were dedicated to support rice cultivation. It is therefore important that water systems for shrimp culture need to be designed in ways that prevent the spread of diseases. The situation could become worse when water gets stagnant and leaks into shrimp ponds (Nguyen & Andrew, 2010).

CONCLUSIONS

Saline intrusion in the VMD is becoming increasingly complex, which makes rural inhabitants and water-based livelihoods exposed to higher risks. Farmers on both sides of the delta are aware of how these affect their livelihoods. The study findings suggested that farmers have proactively shifted farming systems to accommodate new environmental conditions. Crop diversification is seen as one of the most vital adaptation options in dealing with the situation.

While structural systems have been built to control SI, equal attention should be given to relations between farming groups who have encountered conflicts of interest when utilizing water systems for rice and shrimp farming during the dry season. This study calls for collaborative efforts from rice and shrimp farmers to address the issue across the coastal areas in the VMD, particularly under the accelerating impacts of SI. Open space for deliberative decision making and collaborative learning among relevant actors (farmers, extension experts, government officials) therefore needs to be enhanced, making it possible to facilitate the incorporation of farmers' innovative farming practices (successful models) into water management policies (salinity control measures) to accommodate the change.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of government officials and farmers in Kien Giang and Tra Vinh provinces for their participation in the study. We are very grateful to Andalas University and An Giang University for providing sustained support during my Doctoral study. We especially thank Dr. Charles Howie for editing the paper. Lastly, we thank the PEER-USAID projects at Andalas University that provide financial support for this study.

REFERENCES

Afrizal. (2016). *Qualitative research method encouraging the use of qualitative research in various discipline*. Jarkata, Indonesia: Rajagrafindo.

Agrawal, A., Kononen, M., & Perrin, N. (2009). Local institutions and adaptation to climate change. In *Social dimensions of climate change.* Washington, USA: World Bank.

Asian Management and Development Institute. (2016). *Development of shrimp rice system in the Mekong Delta*. Ha Noi, Vietnam: USAID MEKONG ARCC and AMDI.

Bowyer, P., Bender, S., Rechid, D., & Schaller, M. (2014). *Adapting to climate change: Methods and tools for climate risk management.* Hamburg, Germany: Climate Service Center.

Burton, I., Diringer, E., & Smith, J. (2006). *Adaptation to climate change: International policy options*. Arlington, USA: Pew Center on Global Climate Change.

Climate Change-Agriculture and Food Security-Southeast Asia. (2016). *The drought and salinity intrusion in the Mekong River Delta of Vietnam: Assessment report*. Hanoi, Vietnam: CGIAR Research Centers in Southeast Asia.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. London, England: Sage Publications.

Dang, N. K., Nguyen, B. V., & Nguyen, T. H. (2007). Water use and competition in the Mekong Delta, Vietnam. In T. B. Tran, T. S. Bach, & F. Miller (Eds.), *Challenges to sustainable development in the Mekong Delta: Regional and national policy issues and research needs* (pp. 143-188). Bangkok, Thailand: The Sustainable Mekong Research Network.

de Vaus, D. A. (2002). *Surveys in social research*. New South Wales, Australia: Allen and Unwin.

Estellès, P., Jensen, H., Sánchez, L., & Vechiu, G. (2012). *Sustainable development in the Mekong Delta*. Aarhus N, Denmark: University of Aarhus, Center for Environmental Studies.

Institute of Policy and Strategy for Agriculture and Rural Development (IPSARD). (2016). *Drought and saline intrusion in the Mekong Delta - Adaptations from rice farmers, local goverment and solutions*. Hanoi, Vietnam: Author.

Joint Assessment Team. (2016). *Viet Nam drought and saltwater intrusion rapid assessment report*. Hanoi, Vietnam: Ministry of Agriculture and Rural Development.

Käkönen, M. (2008). Mekong Delta at the crossroads: More control or adaptation? *Ambio: A Journal of the Human Environment, 37*(3), 205-212.

Le, H. D., Li, E., Nuberg, I., & Bruwer, J. (2014). Farmers' perceived risks of climate change and influencing factors: A study in the Mekong Delta, Vietnam. *Environmental Management, 54*(2), 331-345.

Le, P. D. (2017). *Solutions to development the Mekong Delta under natural and human stresses.* Paper presented at the Conference on Sustainble and Climate change Resilience Development of the Mekong Delta of Vietnam, Can Tho city, Vietnam.

Le, T. A., Chu, H. T., Miller, F., & Bach, S. T. (2007). Flood and salinity management in the Mekong Delta, Vietnam. In T. B. Tran, T. S. Bach, & F. Miller (Eds.), *Challenges to sustainable development in the Mekong Delta: Regional and national policy issues and research needs* (pp. 18-68). Bangkok, Thailand: The Sustainable Mekong Research Network.

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., ... & Rockström, J. (2010). Resilience and vulnerability: Complementary or conflicting concepts? *Ecology and Society, 15*(3), 1-26.

Ministry of Agriculture and Rural Development. (2017a). *Strategies for water management in the Mekong Delta to adapt to climate change situation*. Paper presented at the Conference of sustainable and climate resilience development of the Mekong Delta of Vietnam, Can Tho, Vietnam.

Ministry of Agriculture and Rural Development. (2017b). *Erosion of river bank and coastline in the Mekong Delta and solutions to climate*

change. Paper presented at the Conference of sustainable and climate resilience development of the Mekong Delta of Vietnam, Can Tho, Vietnam.

Ministry of Natural Resources and Environment. (2016). *Scenarios for climate change and sea level rise in Vietnam*. Hanoi, Vietnam: Author.

Nguyen, A. N. (2017). Historic drought and salinity intrusion in the Mekong Delta in 2016: Lessons learned and response solutions. *Vietnam Science and Technology, 1*(1), 93-96.

Nguyen, B. T., Lam, H., & Thach, S. P. (2012). Participatory vulnerability analysis: A case study from saline intrusion in the Mekong Delta. *Can Tho University Scientific Journal, 24b*, 229-239.

Nguyen, D. A. (2008). *Salt intrusion, tides and mixing in multi-channel estuaries* (Doctoral thesis), UNESCO-IHE Institute for Water Education, Delft, the Netherlands.

Nguyen, P. T. M. (2016a). *Saline intrusion in the Mekong Delta: Causes, impacts and adaptive solutions*. Hanoi, Vietnam: Ministry of Science and Techology of Vietnam.

Nguyen, T. C. (2016b). Saltwater intrusion – An evident impact of climate change in the Mekong and propose adaptable solutions. *American Journal of Environmental and Resource Economics, 1*(1),1-8.

Nguyen, T. H. (2016c). *Vulnerability to saline intrusion and adaptation options for rice and fish farming households in the Mekong Delta of Vietnam* (Doctoral thesis), Mahidol University, Nakhon Pathom, Thailand.

Nguyen, T. T., & Andrew, F. (2010). Learning from the neighbors: Economic and environmental impacts from intensive shrimp farming in the Mekong Delta of Vietnam. *Sustainability, 2*(7), 2144-2162.

Nguyen, V. D., & Huynh, T. N. (2014). Research to adjust Nam Mang Thit salinity control project to achieve criteria for buidling new rural region in Tra Vinh province. *Journal of Water Hydrology and Technology, 20*, 1-27.

Office of Agriculture and Rural Development in Cau Ngang. (2016). *Report for end of year 2015 and strategy for next year 2016 in Cau Ngang district.* Tra Vinh, Vietnam: Author.

Office of Agriculture and Rural Development in Cau Ngang. (2017). *Report for end of year 2016 and strategy for next year 2017 in Cau Ngang district.* Tra Vinh, Vietnam: Author.

Pham, V. H. T., & Febriamansyah, R. (2017). *Exploring forms and factors affecting collective adaptation to salt water intrusion in the Mekong delta of Vietnam.* Paper presented at the The XVI Biennial IASC Conference - Practicing the commons: self-governance, cooperation, and institutional change, Utrecht University, the Netherlands. Retrieved May 17, 2017, from http://dlc.dlib.indiana.edu/dlc/handle/10535/10412

Pham, V. H. T., Febriamansyah, R., Afrizal, & Tran, T. A. (2018). Government intervention and farmers' adaptation to saline intrusion: A Case study in the Vietnamese Mekong Delta. *International Journal on Advanced Science, Engineering and Information Technology, 8*(5) 2142-2148.

Rambo, A. T. (1983). *Conceptual approaches to human ecology*. Hawaii, USA: East-West Environment and Policy Institute.

Renaud, F. G., Le, T. T. H., Lindener, C., Guong, V. T., & Sebesvari, Z. (2015). Resilience and shifts in agro-ecosystems facing increasing sea-level rise and salinity intrusion in Ben Tre Province, Mekong Delta. *Climatic Change, 133*(1), 69-84.

Roslina, K. (2018). Contribution of brackish and freshwater aquaculture to livelihood of small-scale rural aquaculture farmers in Kedah, Malaysia. *Pertanika Journal of Social Sciences & Humanities, 26*(3), 1301-1321.

Smit, B., & Pilifosova, O. (2003). Adaptation to climate change in the context of sustainable development and equity. *Sustainable Development, 8*, 879-912.

Southern Institute of Water Resources Research. (2015). *Report on saltwater intrusion situations in the Mekong Delta*. Retrieved May 10, 2016, from www.vncold.vn/Modules/CMS/Upload/10/.../150420/ManDBSCLToadam6415.pdf

Southern Institute of Water Resources Research. (2017). *Saltwater intrusion forecast at estuaries in coastal areas of the Mekong delta and suggested solutions*. Ho Chi Minh, Vietnam: Author.

To, P. T., Kam, S. P., Chu, T. H., Le, C. D., Nguyen, T. K., Barr, J., & Ben, D. C. (2003). Impact of seawater intrusion control on the environment, land use and household incomes in a coastal area. *Paddy and Water Environment, 1*(2), 65-73.

Tran, D. H. (2009). *Finding solutions for water irrigation in the Mekong Delta of Vietnam*. Retrieved February 20, 2018, from http://www.khoahoc.net/

Tran, T. A., & Le, P. T. (2011). *Impacts of saline intrusion on poor households'livelihoods in coastal areas of Ben Tre province*. A research report for RDViet program. Thừa Thiên Huế, Vietnam: Hue University of Agriculture and Forestry.

Tran, T. A., Nguyen, T. H., & Vo, T. T. (2019a). Adaptation to flood and salinity environments in the Vietnamese Mekong Delta: Empirical analysis of farmer-led innovations. *Agricultural Water Management*, *216*, 89-97.

Tran, T. N., Vo, L. P., Vu, V. N., & Ho, Q. B. (2019b). Salt intrusion adaptation measures for sustainable agricultural development under climate change effects: A case of Ca Mau Peninsula, Vietnam. *Climate Risk Management, 23*, 88-100.

Vietnam Institute of Meteorology - Hydrology and Environment. (2010). *Climate change effects on water resource and adaptation in the Mekong Delta of Vietnam*. Hanoi, Vietnam: Author.

Vo, D. T. (2014). Evaluate community adaptive capacity indices to salinity to agricultural production activities at coastal areas in Tra Vinh province. *Can Tho University Scientific Journal, 36*, 64-71.

Vo, T. K. (2012). Hydrology and hydraulic infrastructure systems in the Mekong Delta, Vietnam. In F. G. Renaud & C. Kuenzer (Eds.), *The Mekong Delta system: Interdisciplinary analysis of a River Delta* (pp. 49-81). Dordrecht, The Netherlands: Springer.

Walliman, N. (2006). *Social research method*. London, England: Sage Publications.

APPENDICES

Appendix 1

Profit from integrated shrimp rice and intensive shrimp system (N=235)
Unit: 1,000 Dong/ha

	Integrated shrimp rice system	Intensive shrimp system
Turnover	81,144	654,921
Cost (*)	16,584	324,316
Profit	64,559	330,605

Source: Household interviews (2017-2018);
Note: (*): Including family labour
1USD = 23,160 VN Dong, (exchange rate on 18th March 2019)

Appendix 2

Profit rate of black tiger shrimp in Cau Ngang district from 2015-2017

Year	Rate of profit (%)		
	Profit earning	Break-even	Loss
2015	39.6	8.7	51.7
2016	59.6	7.1	33.3
2017	63.1	3.6	33.3
Average	54.1	6.5	39.4

Source: Office of Agriculture and Rural Development in Cau Ngang district (2016, 2017)