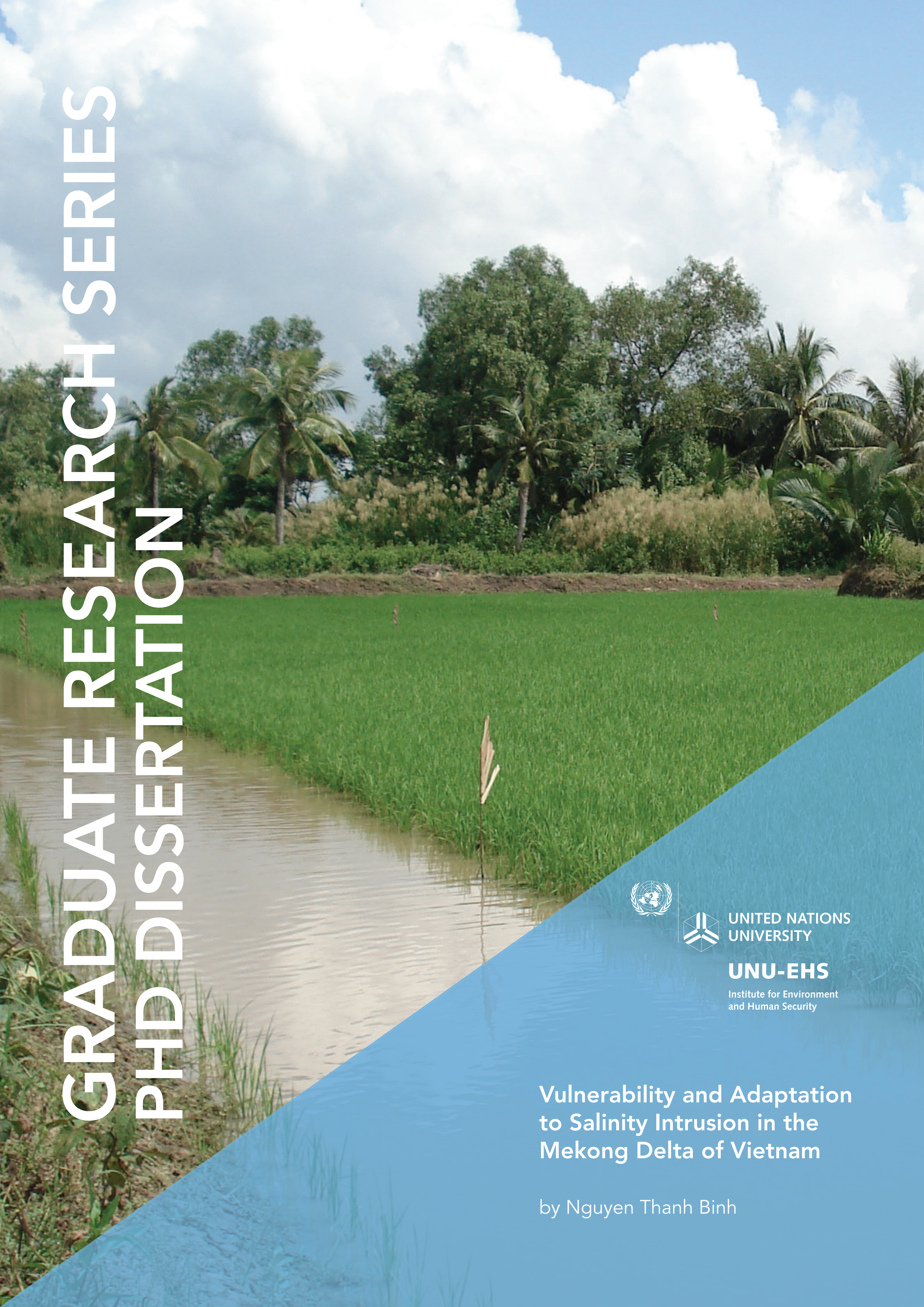

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Nguyen Thanh Binh

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Abstract

The overall objective of this study is aimed at measuring the vulnerability of different social groups to salinity intrusion and related issues in coastal communities of the Mekong delta to improve our understandings on slow-onset hazards as salinity intrusion which receive less attention on one hand and help decision makers develop suitable adaptation measures on the other hand. The study employed a combination of quantitative and qualitative research methods to measure vulnerability. First, a participatory vulnerability analysis approach was used to identify the most vulnerable groups and their capacities. Second, by using factor analysis technique based on 512 respondents at household level, twenty indicators belong to three elements of vulnerability such as exposure, susceptibility and adaptive capacity were selected to construct a vulnerability index. The results showed that salinity intrusion, freshwater scarcity, drought and tidal influences are the most important hazards in the coastal areas of the Mekong delta and they seem to be increased recent years. To cope with and to adapt to such hazards the governments and local people have been developed many strategies and measures including dyke buildings, changes in farming techniques, financial supports for production recovery from disasters, ground water exploitation and income diversifications. However, the current adaptation options have shown some limitations because they do not fully consider the differences in terms of ecological, social and economic environments. The results obtained with the help of composite indicators depicted that the vulnerability of people highly depends on such conditions. Therefore, future adaptation strategies should take into account these in order to identify different social groups, especially the most vulnerable ones as the poor, minority ethnic groups and people living outside the dyke systems. Through the study, a VAFSLO framework (**V**ulnerability **A**ssessment **F**ramework for **Slo**w-onset hazard) and LIWISLO approach (**Li**ving **Wi**th **Slo**w-onset hazard) have been developed which can be used for vulnerability assessment and management of slow-onset hazards, especially under climate change and sea level rise contexts.

Kurzfassung

Das Ziel dieser Studie ist die Messung von Vulnerabilität von ausgewählten Küstengemeinden des Mekong Deltas in Vietnam gegenüber Salzwasserintrusion. Bisher hat diese schleichende Naturgefahr vergleichsweise wenig Aufmerksamkeit von Forschung und Politik erhalten. Die vorliegende Arbeit zielt daher darauf ab, Entscheidungsträgern mögliche Anpassungsmöglichkeiten lokaler Gemeinden aufzuzeigen. Zur Messung der Vulnerabilität werden in dieser Arbeit eine Kombination aus quantiativen und qualitativen Methoden herangezogen. Durch eine partizipative Vulnerabilitätsanalyse wurden in einem ersten Schritt die am stärksten gefährdeten Gruppen und deren Kapazitäten identifiziert. In einem zweiten Schritt wurde mithilfe der Faktorenanalyse zwanzig Indikatoren identifiziert und drei Vulnerabilitätselemente klassifiziert: Exposition, Anfälligkeit und Anpassungskapazität. Als Datengrundlage diente die Befragung von 512 Haushalten. Die Ergebnisse zeigen, dass Salzwasserintrusion, Süßwasserknappheit, Dürre und den Einluss der Gezeiten die wichtigsten Naturgefahren in den Küstenregionen des Mekong Deltas darstellen. Alle vier Naturgefahren scheinen sich in jüngerer Vergangenheit zu intensivieren. Bewältigungs- und Anpassungsstrategien von lokalen Regierungen und Gemeinden schließen den Deichbau, technische Veränderung in der Argrawirtschaft, finanzielle Unterstützung für den Wiederaufbau, Grundwassererschließung sowie Einkommensdiversifizierung ein. Diese Anpassungstrategien sind oftmals durch eine Missachtung von ökologischen, sozialen und ökonomischen Rahmenbedingungen lokaler Gemeinden gekennzeichnet. Die Ergebnisse der Faktorenanalyse in dieser Studie deuten allerdings darauf hin, dass gerade diese Rahmenbedingungen von entscheidender Beudetung für lokale Vulnerabilität sind. Zukünftige Anpassungsstrategien sollten diese Rahmenbedingungen daher beachten um ihre Wirkung auch für marginalisierte soziale Gruppen wie etwa ethnische Minderheiten und Bewohner außerhalb des Deichsystems zu entfalten. Auf Grundlage der empirischen Ergbnisse entwickelt diese Studie die VAFSLO (**V**ulnerability **A**ssessment **F**ramework for **Slo**w-onset hazard) und LIWISLO (**Li**ving **Wi**th **Slo**w-onset hazard) Analyserahmen für die Vulnerabilitätsmessung und für das Management von schleichenden Naturgefahren im Kontext des Klimawandels und des Meeresspiegelanstiegs.

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List of abbreviations

AC	Adaptive Capacity
AGSO	An Giang Statistical Office
ANOVA	Analysis of Variance
ASI	Adaptive Capacity Sub-index
AW	Autumn-Winter (rice crop)
BAV	Basic Asset Values
CDR	Crop Damage Ratio
CHR	Chronic Illness Ratio
CIR	Crop Income Ratio
COH-TV	Center of Hydrometeorology in Tra Vinh
CTSO	Can Tho Statistical Office
DER	Dependency Ratio
DARD-TV	Department of Agriculture and Rural Development in Tra Vinh
DARD-TC	Department of Agriculture and Rural Development in Tra Cu
DTI	Debt to Total Income
E	Exposure
EOD	Effects of Drought
EOT	Effects of Tide
EOS	Effects of Salinity Intrusion
ESI	Exposure Sub-index
GDP	Gross Domestic Product
GSO	General Statistics Office
HCR	Health Cost Income Ratio
HHS	Household Survey
HIR	Health Insurance Ratio
HYV	High Yielding Varieties
ILR	Illiteracy ratio
IPC	Income per capita
IPCC	Intergovernmental Panel on Climate Change
KI	Key Interview
LIWISLO	Living With Slow-onset Hazard
MARD	Ministry of Agriculture and Rural Development
MDI	Mekong Delta Development Research Institute
MONRE	Ministry of Natural Resources and Environment
MRC	Mekong River Commission
NIS	Number of Income Sources

NOH	Number of Hazards
NRT	Number of Received Training (courses)
NWS	Number of Water Sources
OECD	Organization of Economic Cooperation Development
PLA	Protected land area
PPC-TV	Provincial People’s Committee in Tra Vinh
PVA	Participatory Vulnerability Analysis
S	Susceptibility
SA	Summer-Autumn (rice crop)
SSI	Susceptibility Sub-index
SES	Social Ecological System
SLR	Sea Level Rise
SMTS	South Mang Thit Sub-project
SPC	Saving per capita
SRHMC	Southern Regional Hydro-Meteorological Center
SRV	Socialist Republic of Vietnam
TLA	Total Land Area
TCSO	Tra Cu Statistical Office
TVSO	Tra Vinh Statistical Office
UC	Upland Crop
UNISDR	United Nations International Strategy for Disaster Reduction
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
USD	United States Dollar
USDA	United States Department of Agriculture
VAFSLO	Vulnerability Assessment Framework for Slow-onset Hazard
VISI	Vulnerability Index to Salinity Intrusion
VND	Viet Nam Dong (currency)
WIR	Wage income ratio
WOC	Working outside of community
WS	Winter-Spring (rice crop)

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Chapter 1: INTRODUCTION

1.1 Research rationale

Through vulnerability concept and vulnerability assessment to natural hazards are not new, but further research is still needed, particularly in case of slow-onset hazards. In the last two decades, a large number of vulnerability studies were carried out intensively around the world covering different types of hazards and risk contexts such as flood, tsunami, typhoon, drought, climate change, pollution, poverty, food insecurity and famine, human insecurity, etc; at various scales from global to community and household level; using several different methods and data sources, for example qualitative and/or quantitative approaches, primary and/or secondary data (Table 1.1). Despite the remarkable achievements from high quality vulnerability research, current knowledge on this area is still limited as being discussed in the following sections.

Table 1.1: Selected intensive vulnerability research activities in the last two decades

Issues and contexts		**References**
Theory	Terminology	Cannon, 1994; Wisner et al, 2004; Adger, 2006; Birkmann, 2006; Gallopin, 2006; Janssen and Ostrom, 2006; Schneiderbauer and Ehrlich, 2006; McLaughlin and Dietz, 2008; Cutter et al, 2009; Turner, 2010; Costa and Kropp, 2012; Birkmann, 2013
	Conceptual framework	Cannon, 1994; Turner et al, 2003; Wisner et al, 2004; Birkmann, 2006; Birkmann; 2013; Hinkel and Klein, 2006; Kok et al, 2006; Schneiderbauer and Ehrlich, 2006; Eakin and Bojorquez-Tapia, 2008; O'Brien, 2009; Cutter et al, 2009; Birkmann et al, 2012; Costa and Kropp, 2012
Hazard types	Flood	Wisner et al, 2004; ; Pelling, 2006; Queste and Lauwe, 2006; Cardona, 2007; Balica and Wright, 2010; Shen, 2010; Fekete, 2010; Damm, 2010; Kien, 2011; Rafiq and Blaschke, 2012; Balica et al, 2012; Tuan, 2014
	Drought, water scarcity	Kiunsi, 2006; Pelling, 2006; Collins and Bolin, 2007; Rafiq and Blaschke, 2012; Naumann et al., 2014
	Typhoons	Wisner et al, 2004; Cardona, 2007;
	Cyclone	Patnaik and Narayana, 2005; Pelling, 2006; Rafiq and Blaschke, 2012
	Tsunami	Birkmann et al, 2006; Hagen, 2013
	Earthquake	Wisner et al, 2004; Bolin et al, 2003; Pelling, 2006; Rafiq and Blaschke, 2012; Hagen, 2013
	Salinity intrusion	Miah et al, 2004; Rahman and Bhattacharya, 2006; Sam, 2006; Binh, 2010; Birkmann et al, 2012; Seal and Baten, 2012
	Climate change	Zorrilla, 2008; Cutter et al, 2009; Hahn et al, 2009; Wongbusarakum and Loper, 2011; McDowell and Hess, 2012; Dang et al, 2012; Shah et al, 2013

Social and economic context	Agriculture, rural livelihoods	Wisner et al, 2004; Patnaik and Narayana, 2005; Parker and Kozel, 2006; Eakin and Bojorquez-Tapia, 2008; Thu and Populus, 2007; Zorrilla, 2008; Hahn et al, 2009; ABARE-BRS, 2010; Damm, 2010; Vincent and Cull, 2010; Kien, 2011; Birkmann et al, 2012; Dang et al, 2012; McDowell and Hess, 2012; Shah et al, 2013
	Industry, urban economic activities	Collins and Bolin, 2007; Hiete and Merz, 2009; Birkmann et al, 2012; Garschagen, 2014
	Coastal areas	King and Adeel, 2002; Patnaik and Narayana, 2005; Birkmann et al, 2006; Hinkel and Klein, 2006; Thu and Populus, 2007; Kakonen, 2008; Kim et al, 2008; Binh, 2010; Uy et al, 2011; Wongbusarakum and Loper, 2011; Balica et al, 2012;
	Inequality (gender, ethnicity, class)	Wisner et al, 2004; Fothergill and Peek, 2004; Bolin, 2006; Parker and Kozel, 2006; Eakin and Bojorquez-Tapia, 2008; Hagen, 2013; Shah et al, 2013
Scale application	Global, regional	Greiving, 2006; Kok et al, 2006; Pelling, 2006; Cardona, 2007; O'Brien, 2009; Balica et al, 2012; Naumann et al., 2014
	National, provincial, district	Patnaik and Narayana, 2005; Queste and Lauwe, 2006; Thu and Populus, 2007; Kim et al, 2008; Damm, 2010; Rafiq and Blaschke, 2012
	Community and household	Bolin et al, 2003; Kiunsi, 2006; Birkmann et al, 2006; Parker and Kozel, 2006; Eakin and Bojorquez-Tapia, 2008; Zorrilla, 2008; Hahn et al, 2009; ABARE-BRS, 2010; Vincent and Cull, 2010; Uy et al, 2011; Wongbusarakum and Loper, 2011; Kien, 2011; Dang et al, 2012; McDowell and Hess, 2012; Shah et al, 2013; Garschagen, 2014
Method use	Qualitative	Shen, 2010; Dang et al, 2012; McDowell and Hess, 2012
	Quantitative, index	Bollin et al, 2003; Greiving, 2006; Kiunsi, 2006; Kok et al, 2006; Queste and Lauwe, 2006; ; Pelling, 2006; Birkmann, 2007; Cardona, 2007; Collins and Bolin, 2007; Eakin and Bojorquez-Tapia, 2008; Kim et al, 2008; Hiete and Merz, 2009; Hahn et al, 2009; ABARE-BRS, 2010; Vincent and Cull, 2010; Balica and Wright, 2010; Kien, 2011; Rafiq and Blaschke, 2012; Balica et al, 2012; Shah et al, 2013
	Mixed	Birkmann et al, 2006; Parker and Kozel, 2006; Zorrilla, 2008; Uy et al, 2011; Wongbusarakum and Loper, 2011; Birkmann et al, 2012; Garschagen, 2014; Tuan, 2014
Data source	Secondary	Bollin et al, 2003; Patnaik and Narayana, 2005; Greiving, 2006; Kok et al, 2006; ; Pelling, 2006; Queste and Lauwe, 2006; Cardona, 2007; Collins and Bolin, 2007; Hiete and Merz, 2009; ABARE-BRS, 2010; Fekete, 2010; Rafiq and Blaschke, 2012; Balica et al, 2012
	Primary	Kiunsi, 2006; Zorrilla, 2008; Hahn et al, 2009; Vincent and Cull, 2010; Kien, 2011; Dang et al, 2012; McDowell and Hess, 2012; Shah et al, 2013
	Both	Birkmann et al, 2006; Parker and Kozel, 2006; Damm, 2010; Uy et al, 2011; Wongbusarakum and Loper, 2011; Birkmann et al, 2012; Garschagen, 2014; Tuan, 2014

1.1.1 Lack of knowledge on slow-onset hazards

In real life disaster management, hazards are typically classified into rapid-onset (also called sudden) and slow-onset (also called creeping) events. By definition, the rapid-onset hazards tend to be of a short time frame and their occurrence can not be predicted far in advance such as earthquakes, cyclones, windstorms, landslides, floods, volcanic eruptions (Twigg, 2004: p248; Siegele, 2012: p5). On the contrary, slow-onset hazards do not occur in a single, distinct event but emerge gradually over time, often based on a confluence of different events (Adamo, 2011: p6). Most discussion of slow-onset hazards focuses on drought but these hazards can also include climate change and sea level rise (Twigg, 2004: p248; Grasso and Singh, 2009: p4; Adamo, 2011: p6). In general, both researchers and policy makers pay less attention to slow-onset hazards because they creep gradually and may not cause serious crisis in their early phases (Grasso and Singh, 2009: p4; Seng and Birkmann, 2011: p6) or because people perceive continuous processes commonly within the range of normal variability instead of beyond the normal range in which the system exists (Gallopin, 2006: p295). However, at a certain stage a combination of stresses may exceed the ability of vulnerable social-ecological systems to cope and there is a risk that the entire system will be subject to collapse because there was no (or late) response. Hence losses from creeping process can affect even more people than sudden-onset hazards (UNOCHA, 2011: p7; Siegele, 2012: p11; Stabinsky and Hoffmaister, 2012: p1). Then, there is a clear need to respond to slow-onset hazards earlier and with more appropriate responses in order to avoid damages to people's livelihoods in certain situation before they reach an acute phase (UNOCHA, 2011: p11). Up to the moment, there is not enough knowledge on how to address slow-onset hazards. It requires more work to enhance our understanding of creeping hazards. Balica et al (2012: p77) recognized that creeping hazards are barely perceptible by society. According to Guppy and Twigg (2013: p5), the chronic crisis are not yet conceptually well defined, well understood or well analyzed. This results in little progress towards analytical or policy frameworks upon which the management of them could be based. Similarly, Siegele (2012: p15) stated that as some of the potentially greatest loss and damage is expected to come from these slow-onset hazards, there is an urgent need to identify effective approaches to manage them. The above mentioned knowledge gap will be recognized and discussed in this study by analyzing the salinity intrusion hazard – perceived as slow-onset event – and its impacts to agriculture and people's livelihoods in the Mekong delta of Vietnam.

1.1.2 Vulnerability assessment based on secondary data rather than primary data

So far a large number of assessment of vulnerability to climate related hazards and disasters has been completed using secondary data rather than primary data. According to recent evaluation by Preston et al. (2011), only 9% of the 45 climate change vulnerability mapping studies they addressed in their study collected some form of primary empirical data; on the contrary, most were dependent on secondary data from various sources to construct the index. Invariably, data quality and availability can cause some challenges in the later approach because researchers in many cases have to structure their analytical framework around available secondary data, have to be satisfied with inconsistent or missing data, and sometimes must combine data collected at different temporal and spatial scales (Cutter et al, 2009: p13; Hahn et al, 2009: p75; Shah et al, 2013: p127). Moreover, climate change vulnerabilities and responses depend not only on changes in climate parameters but also on interaction between these parameters and changes over the same periods under certain socio-economic conditions (Parry et al, 2007 in Kriegler et al, 2012: p809). Therefore, it is necessary to carry out research with people in the field to understand not only who may be more or less vulnerable, but also what factors influence them (Fothergill and Peek, 2004: p105; Eakin and Bojorquez-Tapia, 2008: p112). In addition to more locally oriented case studies, some researchers employed index approach at household level to assess their exposure, susceptibility and adaptive capacity to natural disasters and climate variability in order to provide insight for better local climate change adaptation and mitigation planning (Hahn et al, 2009; Shah et al, 2013). Even some local vulnerability assessments have been carried out in recent years but the fact remains that there are no commonly shared sets of perspectives about socio-ecological settings across the world, hence the greater impetus is the need for evidence-based and empirically derived information to support the mitigation planning pressures, and the scientific support for climate change policies under local conditions (Cutter et al, 2009: p13; Kriegler et al, 2012: p810). Considered these challenges, this study will contribute by constructing a vulnerability index to salinity intrusion in the Mekong delta of Vietnam based on primary empirical data and observations at household level.

1.1.3 Issue of ethnicity in current vulnerability assessment

According to Wisner et al (2004: p7), to understand disaster we must not only know about the types of hazards that may affect people, but also the different levels of vulnerability of different groups of people. It is increasingly recognized that ethnicity, an ensemble of cultural characteristics and interaction patterns that distinguish one group from another, is a central factor to understand people vulnerability (Fothergill et al, 1999; Wisner et al, 2004; Bolin, 2006). Back in the history, ethnic issue has been concerned in geographic disaster research since the 1906 San Francisco earthquake and it was mentioned again in the agenda for hazards research of the 1970s; however, ethnicity is typically not investigated in any real depth in the current disaster literature because existing studies on ethnic differences cover such a wide spectrum of time, disaster event, place and ethnic groups (Fothergill et al, 1999; Bolin, 2006). Taking into account the above challenges in risk analysis and vulnerability assessment, this dissertation will provide an empirical analysis showing how different ethnic groups are, in a variety of rural socio-ecological settings, vulnerable to salinity intrusion hazard in the Mekong delta of Vietnam, and what key factors contribute to different levels of their vulnerability.

1.1.4 Need for a mixed-approach for vulnerability assessment

Vulnerability assessment can be carried out by qualitative or quantitative approach or both. In qualitative methods, vulnerability is analyzed by describable characteristics whereas under quantitative way it is measured using quantifiable characteristics (Chiwaka and Yates, 2005: p10). The literature review reveals that most publications have employed quantitative approaches to measure vulnerability to climate variability and adaptation to climate related hazards at different levels in different socio-ecological contexts whereas the use of qualitative approach or combination of qualitative and quantitative ways receives little attention in practice (Cutter et al, 2009; Birkmann, 2006; Balica et al, 2012; Table 1.1). However, using simultaneously different methodologies to assess vulnerability provides a broader picture of the past and current vulnerability (Birkmann et al, 2006: p329). Considering the dynamic nature of vulnerability, there is a need to enhance our understanding of vulnerability through developing more comprehensive and holistic approaches (Birkmann, 2006; 2013; Balica et al, 2012: p73). Besides, there are several facets of vulnerability which are hardly measurable by good quantitative indicators; hence, the use of a mixed approach is recommended. Therefore, vulnerability assessment to salinity intrusion in this study will be carried out by a mixed approach, a combination of both qualitative and quantitative tools for a better understanding of the historical vulnerability and potential adaptation strategies to reduce the hazard impacts.

1.1.5 Why focusing on salinity intrusion in the Mekong delta

There are three main reasons regarding to research on vulnerability assessment and adaptation to salinity intrusion in the coastal area of Mekong delta. Firstly, rapid growth in economy and population have caused adverse impacts on coastal socio-ecological systems (SES). Secondly, the problem of salinity intrusion has been increasing particularly in low-lying areas like the Mekong delta due to sea level rise, climate change and upstream infrastructure development. Finally, there is a lack of social studies on risk related to salinity intrusion in the area.

Rapid growth causing negative impacts on coastal socio-ecological systems

At global scale, many studies show that both economic activities and population have increased rapidly in the coastal areas, particularly in most Asian countries including the Mekong delta. They caused adverse impacts on environmental quality and living resources (King and Adeel, 2002; Nicholls et al, 1999; Nicholls, 2004; Thu and Populus, 2007; Be et al, 2007; Seal and Baten, 2012). It was estimated in the 1990s that about 21% of the world's population live within 30 km of the coast and this population is growing twice as fast as the global average (Nicholls et al, 1999: p69). Due to the large and rapidly growing coastal population, resources have been over-exploited for anthropogenic activities including agriculture, aquaculture, infrastructure, industry, and tourism resulting in losses of coastal wetlands and causing environmental pollution (King and Adeel, 2002; Nicholls et al, 1999; Nicholls, 2004; Binh et al, 2005; Thu and Populus, 2007; Be et al, 2007). Study by Nicholls (2004) emphasized that the rate of coastal wetland losses through human destruction is even bigger than as estimated by different sea level rise scenarios. This suggests that the role of development pathways needs to be scrutinized (Nicholls, 2004: p69).

The Mekong delta of Vietnam has also experienced the same process as other coastal regions in the world. Its population increased by 5.0 million people in the last three decades thus population density reached 429 inhabitants per km^2 in 2012. Thus the delta is one of the most populated areas in the country (GSO, 2004; GSO, 2013). Population growth has increased the pressures on coastal resources for food security and livelihoods of the people living in the delta (Binh et al, 2005; Thu and Populus, 2007; Be et al, 2007). Since 1990s numbers of irrigation infrastructures have been invested for expanding and intensifying both agriculture and aquaculture. As result, Vietnam becomes one of the largest rice and fish/shrimp exporters in international market nowadays (Ut and Kajisa, 2005; Tuan et al., 2007; Birkmann et al, 2012; Dung, 2012). Developments of agriculture and aquaculture here contribute to socio-economic improvement on one hand but harm the coastal ecosystems on the other hand. In addition, vulnerable groups (i.e. the poor, minority ethnic groups) who rely on natural resources were lagging behind this development process (AusAID, 2004; Binh, 2010). So far, much research have been done to assess socio-economic development in the Mekong delta and evaluate coastal resource degradation due to economic growth such as environmental pollution, losses of mangrove and biodiversity (Kenji and Hironochi, 2002; Binh et al, 2005; De, 2006; Be et al, 2007; Hanh and Furukawa, 2007; Ha, 2012; Garschagen et al, 2012). However, the questions of how social-ecological changes affect different social groups in the Mekong delta and how they deal with such transformations are still missing and need to be explored.

Problem of salinity intrusion

Salinity intrusion becomes one of the most important hazards in the Mekong delta because its economy is still dominated by the agricultural sector. Additionally, its downstream location predestines it to be more vulnerable to climate change and hydropower development in upstream countries. The Mekong delta is known as one of the most productive and intensively cultivated agricultural areas in all of Asia and proud to be the rice bowl of Vietnam (Hook et al, 2003; GSO, 2013). Approximately covering 12% of the country's total land areas and 21% of its population, the delta produced 24.3 million tons of rice or 56% of the Vietnam's total rice production in the year 2012 (GSO, 2013). This achievement is possible due to the efforts of producers and suitable policies from the government, in which the development of dykes and sluice gates to control sea water intrusion in the coastal provinces are important cornerstones (Ut and Kajisa, 2005; Hoi, 2005; Tuan et al., 2007; Kotera et al, 2008; Binh, 2010). Despite big advantages of dykes, the Vietnamese Ministry of Agriculture and Rural Development (MARD, 2011) reported that, out of 650,000 ha of rice grown in the lower delta, annually about 100,000 ha of rice is at risk to salinity intrusion. It becomes more severe in case of a drought in the early or late periods of the rainy season. For example, the economic loss by salt water intrusion in 2005 (one of the driest years recently) was estimated at USD 45 million or 1.5% of annual rice production in the Mekong delta (MARD, 2005). Besides, its long coastline and low topography the Mekong delta has been considered as one of the most vulnerable hotspots to climate change and sea level rise in the world (WB, 2004; USGS, 2010; MONRE, 2012). Under this context sea water continues to intrude further inlands causing inundation and livelihood destruction. Moreover, many water use projects from upstream particularly hydropower and irrigation development will affect water flow regimes and may cause more salinity intrusion in the dry season. Using the MIKE11 computer program package to simulate salinity intrusion in the Mekong delta under different climate change and upstream flow reduction scenarios, Tran and Likitdecharote (2010) proved that saline intrusion area will be expanded in comparison to the baseline scenario in 1998, the most serious salinity intrusion in the past. Therefore, it is clear that the salinity hazard becomes more and more problematic in the Mekong delta. In this regard, the study will analyze salinity data trend to have better understanding of past and present changes in the hazard and to assess their impacts on agriculture and livelihoods in different rural socio-ecological settings in the delta.

Lack of social study on risk to salinity intrusion

To date the vast majority of research on natural hazards in the Mekong delta tends to focus on loss estimation and modeling rather than social impacts, especially the case of salinity intrusion. Some recent studies on salinity related hazards are reviewed and discussed as follow.

The study by Kam et al (2000) is using remote sensing, GIS and hydraulic modeling to provide useful information helping to understand the dynamic changes in rice cropping systems in response to changes in agro-hydrological conditions resulting from infrastructure development to control saline water intrusion in the Ca Mau Peninsula of the Mekong delta. However, the authors also recognize that it is necessary to investigate the effect of changing bio-physical conditions on the rural livelihoods.

The study by Hanh and Furukawa (2007) on "impacts of sea level rise on coastal zone of Vietnam" reveals serious impacts of sea level rise on the coastal zone such as loss of wetland and other low land; increased vulnerability to flooding and storm events; accelerated erosion along the coasts and river mouths; and increased salinity of estuaries, saltwater intrusion into freshwater bodies, aquifers and degradation of water quality. They also mentioned that such physical impacts affect directly people living in coastal regions but did not show in detail how local people are affected and the ways people react to the impacts. That is why the authors recommend that Vietnam has to carry out research to evaluate more comprehensively the influence of sea level rise to assess coastal zone vulnerability for devising better intervention policies.

Van (2008) identified some impacts of sea level rise in the Mekong delta by quantitative approach and concluded that sea level rise is likely to increase quickly in the next decades. It would strongly affect hydrological factors and flow regimes in the river and canal systems. It increases saline intrusion and serious flooding, making an adverse effect on the socio-economic development and environment. However, he did not evaluate how the socio-ecological system would be affected by salinity intrusion. Therefore, he suggested further studies as these impacts are required to be assessed and "quantified" as the base for long term adaptation strategies.

Kotera et al (2008) used secondary data in the period of 2003-2005 to assess the consequences of sea water intrusion on rice productivity and land use in the coastal area of the Mekong delta. It showed that rice cropping intensities are potentially limited by the salinity level while average salinity concentration tends to increase in most districts over the 3 study years. To cope with salinity intrusion, many of the paddy fields in the coastal area have been shifted to aquaculture. Despite these valuable results, they did not investigate the mechanism of changing salinity level and how land use changes impact different social groups in the coastal communities.

1.2 Research objectives

Given the above identified knowledge gaps and challenges, the overall objective of this dissertation is aimed at measuring the vulnerability of different social groups to salinity intrusion and related issues, particularly their susceptibility, exposure and adaptive capacities as well as their adaptation to these hazards in coastal communities of the Mekong delta in the contexts of social, economical and environmental changes. This will improve our understanding of slow-onset hazards which receive less attention in current literature on one hand and help decision makers develop suitable adaptation measures at right time for the most vulnerable groups in different socio-ecological settings on the other hand. Based on this general objective, the research is formulated into four specific objectives:

- To better understand past and present changes in natural hazards, particularly salinity intrusion and to assess their impacts on rural livelihoods in the lower Mekong delta of Vietnam
- To identify different vulnerabilities to salinity intrusion and to evaluate key factors which make households more vulnerable in the context of livelihood changes and socio-economic transformation as well as different ethnic groups and their access to assets
- To develop composite index to measure vulnerability to salinity intrusion in different ecological zones, varying socio-economic settings, economic activities, well-being conditions and ethnicities
- To understand risk perception of local people to natural hazards which may influence their coping and adaptation strategies to reduce the vulnerability today and in the future

1.3 Research questions

From the above objectives, four main research questions and some sub-questions have been formulated as follow:

(1) How do natural hazards, particularly salinity intrusion, and their impacts on rural livelihoods change in the lower Mekong delta of Vietnam?

- How did salinity intrusion develop in the period of 1995 – 2010?
- How does salinity intrusion impact agriculture and rural livelihoods?

(2) Who are vulnerable to salinity intrusion, focusing on their exposure, susceptibility and adaptive capacities in different social-economic settings?

- Which are the vulnerable groups to salinity related issues? What are their characteristics? Which factors make them vulnerable?
- How are they affected? Which actions have been done to cope with and to adapt to the hazards?
- What are potential capacities to reduce the vulnerability?

(3) Which indicators can be used to measure vulnerability to salinity intrusion?

(4) How far are local people aware of natural hazards in the context of sea level rise and climate change?

1.4 Scope of the study

This study involves some important analysis of vulnerability to salinity intrusion in the Mekong delta of Vietnam. However, the questionnaire interviews and primary data were mainly obtained from Tra Vinh province located in the coastal areas of the delta where different social-ecological systems operate providing good contexts to assess vulnerability. Besides, the research focuses on 3 main components of vulnerability as hazard exposure, susceptibility and adaptive capacities to salinity related problems.

1.5 Structure of the dissertation

This dissertation consists of eight chapters.

Chapter one is an introduction chapter that gives readers an important background information related to the topic and necessity to carry out the study. It is continued with the problem statement, objectives of the study, research questions, scope of the study and ends by describing the structure of this thesis structure.

Chapter two reviews the research concepts. Firstly, it provides the definition of hazard, risk and disaster. Secondly, vulnerability is analyzed by comparing different definitions. It discusses vulnerability elements and related terms. Thirdly, it reviews selected vulnerability assessment approaches like quality and quantity. Fourthly, the chapter analyzes coping and adaptation strategies and their differences. Finally, it is completed by introducing the socio-ecological system concept in sustainable development.

Chapter three will deal with the methodology while chapter four describes the research context by giving information on hazards, social-ecological conditions and changes from national to local level at the research sites.

Chapter five, six and seven provide results based on secondary data and the field surveys. They also discuss these results. The fifth chapter analyzes the salinity intrusion trends and their impacts on agriculture in the Mekong delta. The sixth chapter assesses the vulnerability by applying participatory approach to analyze hazard exposure, susceptibility, and adaptation strategies to salinity related problems in different ecological zones. The seventh chapter deals with building composite indicators to measure vulnerability to salinity intrusion through household survey data in the coastal communities.

Chapter eight summarizes the conclusions drawn from the research and recommendations to policy makers in order to have suitable adaptations to the hazards. It also contributes to the debate on the theory and better understanding of vulnerability concepts in the context of a slow-onset hazard like salinity intrusion while considering social, economical and environmental changes.

Chapter 2: RESEARCH CONCEPTS

In this chapter, vulnerability related research concepts presented in the current literature are reviewed and discussed to provide a better understanding how these concepts are employed in the context of salinity intrusion in the research site. Therefore, the chapter is split into five main sections: (1) relationship between hazard, risk and disaster, (2) elements and dimensions of vulnerability, (3) vulnerability assessment approaches, (4) coping and adaptation strategies, and (5) the socio-ecological system in sustainable development.

2.1 Hazard, risk and disaster

2.1.1 Hazard

People are more vulnerable when they are not aware of hazards (UNISDR, 2004). According to Brooks (2003) the hazard is defined as an event that might precipitate a disaster but which does not itself constitute a disaster because the hazard only become disaster when people's lives and livelihoods are swept away (Annan, 2003). In this view, hazard is also called "an event with the potential to cause harm" (Jones and Boer, 2004), or "potential threat to humans and their welfare" (Downing and Patwardhan, 2004), or "an event may cause physical damage, economic loss and threaten human life and well-being" (Chiwaka and Yates, 2005). In a broader sense, hazard is defined as ''a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation'' (UNISDR, 2004).

It is necessary to explore the basic characteristics of hazard events (Gravley, 2001 in Schneiderbauer and Ehrlich, 2006). There are many ways to characterize hazards according to their roots as natural, technical, man-made, nuclear, ecological, and so on (Thywissen, 2006). However, the UNISDR (2004) divided hazards into 2 groups including natural hazards (i.e. floods, storms, earthquakes, tsunamis, etc) and human-induced hazards (i.e. industrial pollution, toxic waste, fires, climate change, loss of biodiversity, etc). UNISDR (2004) considered sea level rise as one of human-induced hazards because it is related to environmental degradation. This hazard would increase salinity of rivers and groundwater (Carew-Reid, 2008). Viewed in this light, salinity intrusion could be understood as human-induced hazard. However, hazards can be single, sequential, or combined in their origin and effects, and each hazard is characterized by its location, intensity, and frequency (UNISDR, 2004). Applied in Vietnam, many authors called salinity intrusion in the Mekong delta as a natural phenomenon (Sanh et al., 1998; De, 2006; Tuan et al., 2007). It is clearly not easy to allocate a hazard to one class because hazards may have interrelated causes, particularly those associated with global climate change as landslides, subsidence, drought, storm, floods, sea level rise, etc. (Schneiderbauer and Ehrlich, 2006: p83-84). That is why Garatwa and Bollin (2002) called such events as "socio-natural" hazards. Like this classification, the salinity intrusion event in this study belongs to socio-natural hazard group. Besides, hazards also can be distinguished between rapid-onset and slow-onset events.

- The rapid-onset (also called ongoing, sudden, acute) hazards are defined as that arise suddenly or whose occurrence can not be predicted far in advance (Twigg, 2004: p248). Most hazards are rapid-onset events; for example, earthquakes, cyclones, windstorms, landslides, floods, volcanic eruptions, oil spills, nuclear plant failures, chemical plant accidents, and so on.
- The slow-onset (also called continuous, creeping) hazards relate to incremental and cumulative environmental changes that emerge gradually over time, often based on a confluence of different events (Grasso and Singh, 2009: p4; Adamo, 2011: p6). Most discussion of slow-onset hazards focuses on drought but these hazards may include pollution, sea level rise, desertification processes, ecosystem changes, deforestation, loss of biodiversity, coastal erosion, salinity intrusion, pressures on living marine resources, rapid and unplanned urban growth, etc (Twigg, 2004: p248; Grasso and Singh, 2009: p4; Adamo, 2011: p6).

In general, the slow-onset hazards receive little attention when compared to rapid-onset hazards because they emerge gradually and may not cause serious crises in their early phases (Grasso and Singh, 2009: p4; Birkmann, 2011: p6) or because people perceive continuous processes commonly within the range of normal variability instead of beyond the normal range in which the system exists (Gallopin, 2006: p295). However, at a certain stage a combination of stresses may exceed the ability of vulnerable social-ecological systems to cope and there is a possibility that the entire system will be subject to collapse but there is no (or late) response hence losses from creeping process will affect even more people than sudden-onset hazards (UNOCHA, 2011: p7; Siegele, 2012: p11; Stabinsky and Hoffmaister, 2012: p1). In other words, the slow-onset changes are more likely to be problematic with high potential impacts on socio-ecological systems in the medium or long-term if appropriate interventions are not taken when needed (Grasso and Singh, 2009: p5). Therefore, it is necessary to pay more attention to such slow-onset hazards in term of not only preventive measures but also effective early warning technologies (Grasso and Singh, 2009: p5; Birkmann, 2011: p6). Moreover, there is a need to develop new approaches for identifying and assessing risks related to slow-onset threats due to their specific characters like "creeping" and often associated with different events (Birkmann et al., 2008: p17; Birkmann, 2011: p6). This dissertation deals with an analysis of vulnerability to salinity intrusion and related hazards (i.e. freshwater scarcity and tidal flooding) in the Mekong delta that will contribute to have better understanding of the interaction between social and ecological systems in case of slow-onset hazards in order to call more attention for proper adaptation strategies with the context of social, economical and environmental changes.

2.1.2 Risk

Risk becomes common term in our conversation nowadays. It has many different definitions and colloquial use, depending on the different disciplines and/or economic activities. Thywissen (2006: 470-473p) reviewed fifteen definitions of risk by different scholars and concluded that risk always involves the notion of probability (how often?) and occurrence (when?). Wisner et al. (2004: p49) considered risk as the product of hazard and vulnerability and stated in detail "risk of disaster is a compound function of the natural hazard and the number of people, characterized by their varying degrees of vulnerability to that specific hazard, who occupy the space and time of exposure to the hazard event". Crichton (1999) included also the concept of exposure as shown in "the risk triangle" (Figure 2.1) and stated risk is the probability of a loss, which depends on three elements, hazard, vulnerability and exposure; if any of these three elements in risk increases or decreases, then the risk increases or decreases respectively.

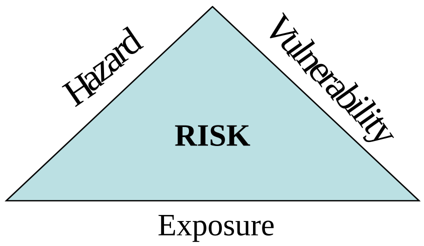


Figure 2.1: The risk triangle

(Source: Crichton, 1999)

Moreover, Thywissen (2006: p491) defined risk as “a function of hazard, vulnerability, exposure and resilience”. According to UNISDR (2004) risk is “the probability of harmful consequences, or expected losses (i.e. deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions”. Wisner et al (2004: p11) stressed that some groups may be at higher level of risk than the others depending on their class, ethnicity, occupation, gender, age, health status and social network. Generally, the term of risk expresses more than the possibility of physical harm because it is influenced not only by physical environment but also social, cultural and historical contexts, including risk perception of people where risk occurs (Sjöberg, 2000; Dolan and Walker, 2004; ISDR, 2004; Plapp and Werner, 2006). Therefore, understanding of perceived risk of different class and ethnic groups is a key to facilitate risk reduction.

2.1.3 Disaster

The concept of disaster relates to hazard and risk (Figure 2.2). According to Thywissen (2006) “every disaster starts with a hazard”. UNISDR (2004) stated “a disaster is a function of the risk process. It results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk”. Similarly, ESPON (2003) considered the disaster as “an impact of the hazard on a community or area that overwhelms the capacity to cope with it”. Wisner et al. (2004: p49) reviewed “there can not be a disaster if there are hazards but vulnerability is nil, or if there is a vulnerable population but no hazard event”. It is clear that the vulnerability and hazards can not be separated under risk or disaster analysis. Hence, Bogardi (2004) stressed that it is important to understand the logical sequence and the stochastic nature of the "hazards–risks–vulnerability" chain. In addition, the hazards only become disaster when people's lives and livelihoods are swept away (Annan, 2003) or the disaster occurs when a significant number of vulnerable people experience a hazard and suffer severe damage and/or disruption of their livelihood system in such a way that recovery is unlikely without external aid (Wisner et al., 2004: p50). From these views, it can be concluded that disaster happens when people are not well prepared for the hazard and unable to recover without external assistance. However, within a community, people's livelihoods are differently affected due to diverging vulnerable conditions of the exposed groups. Therefore, in order to study how people are affected by disasters, it is important to understand not only the hazards themselves but also conditions of vulnerable groups. In this perspective, Birkmann (2006) concluded that "Instead of defining disasters primarily as physical occurrences, requiring largely technological solutions, disasters are better viewed as a result of the complex interaction between a potentially damaging physical event (e.g. floods, droughts, fire, earthquakes, and storm) and the vulnerability of a society, its infrastructure, economy and environment, which are co-determined by human behavior".

Back to the salinity intrusion in the Mekong delta, this hazard really becomes disaster and affects agriculture and natural ecosystems, particularly in "abnormal" years due to climate variability like later rainy season and higher temperature. As a result, it causes livelihood disruptions of local people especially resource poor farmers and Khmer groups (considered as ethnic minority) in the coastal provinces of Vietnam.

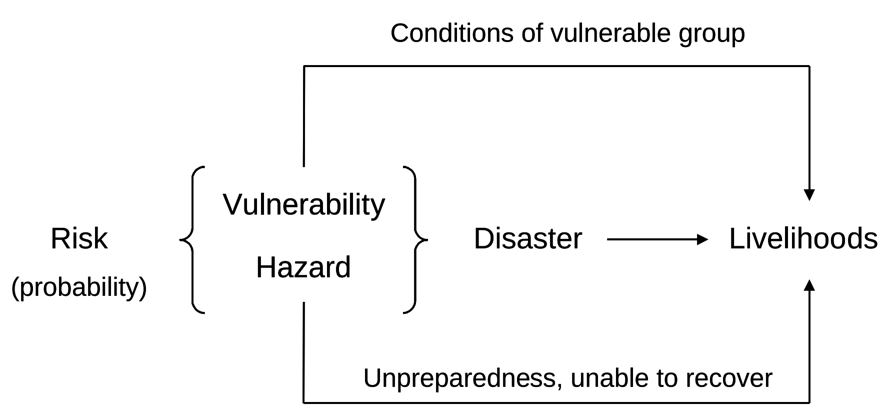


Figure 2.2: Relationship between risk, vulnerability, hazard, disaster and livelihoods

(Based on Blaikie et al., 1994; UNISDR, 2004; Bohle, 2007)

2.2 Vulnerability related concepts

2.2.1 Vulnerability and its dimensions

Traditionally vulnerability concept has been applied in geography and natural hazard research which describes the state of exposure, usually associated with a geographical location rather than with individuals or social groups (Adger, 1999; Füssel, 2007). Today, this term has also been used in other research contexts including ecological, biophysical, social-ecological systems, public health, poverty and development, food insecurity and famine, human security, climate change impacts and adaptation (Adger, 1999; Turner et al., 2003; Bogardi, 2004; Adger, 2006; Gallopin, 2006; Bohle, 2007; Füssel, 2007).

We talk about vulnerability, but what does it mean? It is not easy to answer because the vulnerability concept depends on the context and purpose of its assessment (Brooks, 2003; Adger, 2006; Füssel, 2007). Hence, there is no single correct or best conceptualization of vulnerability that would fit all assessment contexts (Kasperson et al, 2005). Climate change impact scientists often study vulnerability as occurrence and impacts of weather and climate related events or human exposure to hazards (Nicholls et al., 1999) whereas social scientists deal with vulnerability focusing not only exposure to hazards but also the susceptibility (i.e. human and environmental conditions) and resilience (i.e. coping and adaptation) of the system experiencing such hazards (Turner et al., 2003). Therefore, Smit and Wandel (2006) defined "Vulnerability of any system (at any scale) is reflective of (or a function of) the exposure and susceptibility of that system to hazardous conditions and the ability or capacity or resilience of the system to cope, adapt or recover from the effects of those conditions". Brooks (2003) analyzed a difference between biophysical and social vulnerability concepts. According to the author, biophysical vulnerability is concerned with the ultimate impacts of a (natural) hazard event, and is often viewed in terms of the amount of damage (i.e. monetary cost, human mortality, production costs, or ecosystem damage) experienced by a system as a result of an encounter with a hazard. Social vulnerability is not a function of hazard. Certain factors such as poverty, inequality, health, access to resources and social status are likely to determine the vulnerability of communities and individuals to a range of different hazards including non-climate hazards (Brooks, 2003). Finally, he concluded that social vulnerability may be viewed as one of the determinants of biophysical vulnerability.

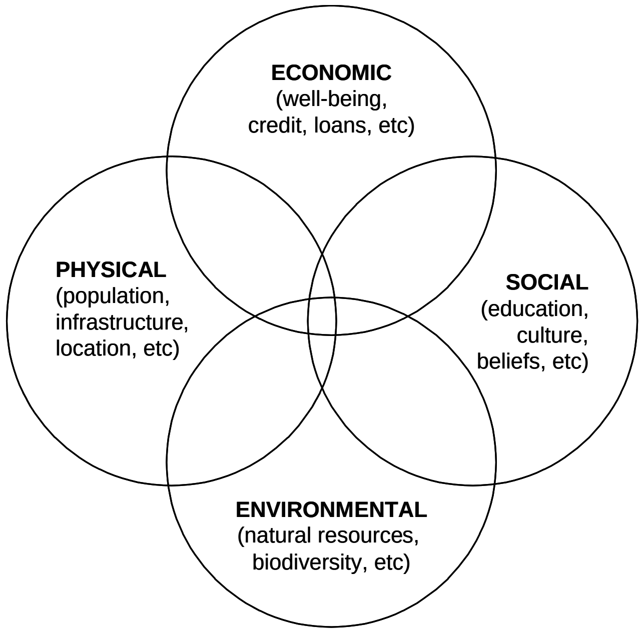


Figure 2.3: Interaction of four vulnerability factors

(Based on UNISDR, 2004)

Some perspectives of vulnerability have been reviewed but it has not been mentioned yet which factors or dimensions shape the vulnerability. According to Bolin (2006) people's vulnerability to environmental threats is shaped by a interaction of socio-spatial and biophysical factors, race/ethnicity and class have proven central in understanding social processes during hazard events. The UNISDR (2004) determined vulnerability by 4 factors including physical, social, economic and environmental (Figure 2.3). Moss et al. (2001) discussed about multiple dimensions of vulnerability and stressed not only on physical-environmental and social-economic but also external assistance (i.e. international arrangements to provide aid). Downing and Patwardhan (2004) suggested that the vulnerability of social systems would encompass the threat, the region, the sector, the group of people, the consequence, and the time period. Vogel and O'Brien (2004) mentioned three defining features of vulnerability: differential concept, scale-dependent and dynamic. Metzger et al. (2005) defined the vulnerability of ecosystems to global change including a particular ecosystem service, a location, a scenario of stressors, and a time span. Cannon (2006) defined social vulnerability as the complex set of characteristics that include a person's exposure to risk through their scores on five components of vulnerability: livelihood strength, well-being and base-line status, self-protection, social protection and governance.

In conclusion, there are many ways to define the vulnerability depending on research field, context and objective. This research is aimed at measuring the vulnerability to salinity intrusion in the context of different social-ecological settings; hence, the term vulnerability is understood as the characteristics of individuals, households, or communities and their situation (i.e. socio-economic status, ecological condition, risk perception, ethnicity groups, etc) that influence their capacity to anticipate, cope with, resist and recover from the impacts of salinity intrusion and related problems.

2.2.2 Elements of vulnerability

Many authors have revealed that vulnerability encompasses 3 key elements: exposure, susceptibility and capacity (IPCC, 2001; Adger and Vincent, 2005; Luers, 2005; Adger, 2006; Smit and Wandel, 2006). In Vietnam, vulnerability to the impacts of climate change is defined as a function of exposure to climate conditions, susceptibility to those conditions, and the capacity to adapt to the changes (MONRE, 2008). According to Smit and Wandel (2006), exposure, susceptibility and capacity are frequently interdependent and strongly affected by social, economic, political and ecological conditions. In this section, the concepts of exposure, susceptibility and adaptive capacity will be examined.

Firstly, ***exposure*** is the likelihood of individuals, household, community, state or ecosystem experiencing the environmental or socio-political stresses which are characterized by frequency, magnitude, duration and real extent of the hazards (Turner et al., 2003; Adger, 2006). Exposure is seen as one of the elements of vulnerability in most literatures. However, Bohle's conceptual framework (2001) considered exposure as external side of vulnerability. Moreover, Gallopin (2006) distinguished exposure from vulnerability and defined "exposure seems to be an attribute of the relationship between the system and the perturbation, rather than of the system itself".

The second concept related to vulnerability is ***susceptibility*** which describes the characteristics that render persons or groups of people generally weak or negatively constituted against stresses and threats (Fekete, 2010). There is a close relationship between exposure and susceptibility within a system because the relative effect of exposure on a system is dependent on the relative susceptibilities (Luers, 2005). Hence, some authors combined exposure and susceptibility together instead of separately (Luers, 2005; Smit and Wandel, 2006).

The third concept is ***capacity*** which refers to the potential to adapt and reduce a system's vulnerability (Luers, 2005). In practice, capacity is the ability to design and implement effective adaptation strategies that depend much on resource availability and accessibility such as natural, financial, institutional, human resources and social networks (Brooks and Adger, 2004). The capacity is context-specific and scale-dependent that varies from country to country, from community to community, among social groups and individuals, and over time (Adger and Vincent, 2005; Smit and Wandel, 2006). Therefore, capacity study has to consider a range of natural and socio-economic variables within a particular condition. Yohe and Tol (2002) suggested eight determinants of capacity including (1) the range of available technological options for adaptation, (2) the availability of resources and their distribution, (3) the structure of critical institutions, (4) the stocks of human capital, (5) the stocks of social capital; (6) the system's access to risk spreading mechanisms, (7) the ability of decision-makers to manage risks and information; and (8) the public's perceived attribution of the source of the stress and the significance of exposure to its local manifestations.

It is also necessary to note that some authors employ the concept *coping capacity* for short-term period and adaptive capacity for long-term adaptation strategies or more sustainable adjustments (Vogel, 2001; Brooks, 2003; Brooks et al., 2005; Schipper and Burton, 2009: p99). Coping capacity can be understood as the means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster (UNISDR, 2004). In term of reaction, coping capacity encompasses those strategies and measures that are directly used upon damage during the event by alleviating or containing the impact or by bringing about efficient relief" (Thywissen, 2006: p489). In other perspective, Brooks (2003) use the term adaptive capacity refers to continuous hazards while coping capacity is more suitable for sudden hazards. Hence, within the context of salinity intrusion and socio-ecological changes in this study, the term adaptive capacity will be used and understood as the ability or potential of individual, household, community, or local government to adjust to salinity intrusion and related problems, to moderate potential damages, to take advantages of opportunities, or to cope with the consequences (based on Gallopin, 2006).

Besides, *resilience* term is also used in social sciences with meaning “The capacity of a system, community or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures” (UNISDR, 2004: p16-17). In Turner and colleagues’ vulnerability framework (2003: p8077) resilience is considered as one of vulnerability components that encompasses coping response (i.e. current programs, policy, autonomous options), impact response (i.e. loss of life, economic production, soil, ecosystem services) and adjustment and adaptation response (i.e. new programs, policy and autonomous options). Generally, the system with highly adaptive capacities can enhance resilience but in many cases highly adaptive systems can lead to a loss of resilience through an increase in adaptability in one place, that may lead to a loss of adaptability and thereby resilience in another place (Schouten, 2009: p4). Hence, it is necessary to stress on the interrelationships not only within the system but also broader scale when carry out vulnerability analysis to capture those interactions.

In summary, societies which are able to respond to or cope with change quickly and easily are considered to have high “adaptability” or “capacity to adapt”; in other word, a system (i.e. a community) that is more exposed and sensitive to a climate stimulus, condition or hazard will be more vulnerable and a system that has more adaptive capacity will tend to be less vulnerable (Smit and Wandel, 2006).

2.3 Vulnerability assessment approaches

So far the vulnerability theory has been reviewed; however, the remaining question is how to assess it or how to measure vulnerability in practice? Generally, vulnerability assessment can be carried out by qualitative or/and quantitative approach (Chiwaka and Yates, 2005: p10; Berry et al., 2006: p190; Birkmann and Wisner, 2006: p7; Birkmann, 2007: p20). In quantitative method, vulnerability is measured using quantifiable characteristics, for example 50 people are likely to be affected by landslides; whereas under qualitative way, vulnerability is analyzed by describable characteristics, for example 50 people who are likely to be affected by landslides are households who lost their land during the war and who were resettled on the river banks (Chiwaka and Yates, 2005: p10). Each of the two has different procedures and tools as well as advantages and disadvantages that will be discussed briefly below.

2.3.1 Qualitative approach

Participatory vulnerability analysis (PVA) is introduced by ActionAid International Organization as one of qualitative way of analyzing vulnerability. In general, PVA approach can be summarized (based on Chiwaka and Yates, 2005) as follow:

PVA is a systematic and multi-leveled process which involves participation of vulnerable people themselves (and related stakeholders). The analysis helps us to understand vulnerability, its root causes and most vulnerable groups, and agree on actions by, with and for people to reduce their vulnerability. PVA uses a step-by-step approach to systematically analyze the causes of vulnerability by: (i) tracking hazards to determine the level of exposure to hazards, causes and effects, (ii) examining unsafe conditions (factors that make people susceptible to risk at a specific point in time), (iii) tracking systems and factors (dynamic pressures) that determine vulnerability, resilience and root causes, and (iv) analyzing capacities and their impact on reducing vulnerability. To obtain data and information, PVA employs many participatory techniques as stakeholder analysis, problem and objective trees, focus group discussion, historical profile, timeline and trend-line analysis, seasonal calendar, vulnerability map, livelihood analysis, community action plan/scenario planning.

The advantages of PVA include: (i) establish links between emergencies and development, (ii) recognize developments or events at national and international level and how these impact on communities' vulnerability, (iii) use the output of local level analysis to inform higher level action and policies, and (iv) empower to take charge of communities' efforts to address their vulnerability. However, as other participatory approaches, the PVA needs an active participation from communities and related stakeholders during PVA process. Besides, the success of PVA exercise depends on the depth of preparation, whereby attitude and skills of facilitators are also important.

2.3.2 Quantitative approach

There are numbers of tools and techniques to measure vulnerability using quantifiable characteristics which are introduced and discussed; for example, Moss et al., 2001; Birkmann, 2006; Birkmann and Wisner, 2006; Birkmann, 2007. Among others, composite indicator is a common approach because ideally this measures multi-dimensional concepts which cannot be captured by a single indicator (like vulnerability) (OECD, 2008: p13). Development process of vulnerability indicators includes nine steps such as define goals, scoping, choose indicator framework, define selection criteria, identify potential indicators, choose a final set of indicators, analyze indicator results, prepare and present report, and assess indicator performance (Birkmann, 2006: p64). The composite indicator also has a number of pros and cons (Table 2.1). Therefore, users should take into account all of these to maximize advantages while minimize disadvantages in order to measure the "right" nature of vulnerability.

Table 2.1: Pros and cons of composite indicator

Pros	Cons
- Can summarize complex, multi-dimensional realities with a view to supporting decision makers - Are easier to interpret than a battery of many separate indicators - Can assess progress of countries over time - Reduce the visible size of a set of indicators without dropping the underlying information base - Thus make it possible to include more information within the existing size limit - Place issues of country performance and progress at the centre of the policy arena - Facilitate communication with general public (i.e. citizens, media, etc.) and promote accountability - Help to construct/underpin narratives for lay and literate audiences - Enable users to compare complex dimensions effectively	- May send misleading policy messages if poorly constructed or misinterpreted - May invite simplistic policy conclusions - May be misused, i.e. to support a desired policy, if the construction process is not transparent and/or lacks sound statistical or conceptual principles - The selection of indicators and weights could be the subject of political dispute - May disguise serious failings in some dimensions and increase the difficulty of identifying proper remedial action, if the construction process is not transparent - May lead to inappropriate policies if dimensions of performance that are difficult to measure are ignored

(OECD, 2008: p13-14)

The literature review reveals that most of the publications have employed a quantitative approach to measure vulnerability at different levels in different socio-ecological contexts whereas the use of qualitative approach or combination of qualitative and quantitative ways receives little attention in practice (Birkmann, 2006; Table 2.2). However, using different methodologies to assess vulnerability at the same time provide a broader picture of the past and current vulnerability (Birkmann et al, 2006: p329). Therefore, vulnerability assessment to salinity intrusion in this study applies both qualitative and quantitative approaches for a better understanding of the historical vulnerability and adaptation strategies to reduce the hazard impacts.

Table 2. 2: Review of different vulnerability assessment approaches

Approaches	Hazards	Tools and data sources	Levels	Sources
Quantitative	Climate change	Composite indicator using household survey data	Community	Shah et al, 2013
Quantitative	Poverty	Composite indicator using household survey data	Sub-district	Samsudin and Kamaruddin, 2013
Quantitative	River floods in Germany	Composite indicators using census data and household survey	County	Fekete, 2010
Quantitative	Climate variability and change in Mozambique	Composite indicator using household survey data	District	Hahn et al., 2009
Quantitative	Rural livelihood vulnerability in Mexico	Indicator-based analysis from household survey data	Household	Eakin and Bojorquez-Tapia, 2008
Quantitative	Social vulnerability in Caribbean States	Composite indicators using statistical data	State	Bernard, 2007
Quantitative	Exposure, socio-economic fragility, lack of resilience in the Americas	Composite indicators employing statistical data	State	Cardona, 2007
Quantitative	Natural hazards in Indonesia	Composite indicator using household survey data	Community	Bollin and Hidajat, 2006
Qualitative	Natural hazards like droughts in Africa, floods in Bangladesh	Participatory techniques, i.e. historical analysis, seasonal calendar, Venn diagram, etc	Community	Wisner, 2006
Qualitative and quantitative	Climate and socio-economic changes to agriculture and species	Secondary data, scenario interpretations	European countries	Berry et al., 2006
Qualitative and quantitative	Tsunami in coastal communities in Sri Lanka	Remote sensing, composite indicators using questionnaires and statistical/census data	Community	Birkmann et al., 2006
Qualitative and quantitative	Sewage impacts in mangroves of East Africa	Semi-structure interview	Household	Crona et al., 2009

2.4 Coping and adaptation strategies

Coping and adaptation become common terms in social research, particularly in climate variability and change related issues. Most of the literature agreed that a distinction between coping and adaptation is a timing issue as coping strategies for short-term and adaptation strategies for long-term (IPCC, 2012: p51). But "how much time" is short or long-term still unclear, hence they are not easily separated from each other.

Wisner et al. (2004: p113) defined “coping is the manner in which people act within the limits of existing resources and range of expectations to achieve various ends. In general this involves no more than managing resources, but usually it means how it is done in unusual, abnormal and adverse situations”. Therefore, coping can be perceived as any activity to solve the actual problems immediately like moving to safe places under windstorms or selling a piece of land to deal with health issues. Like this view, Schipper and Burton (2009: p3) agreed that too much deployment of coping strategies can lead to depletion of assets which can cause more vulnerability to hazards later.

Adaptations are manifestations of adaptive capacity (Smit and Wandel, 2006). There are numerous adaptation definitions but they generally aim to reduce vulnerability (Pielke, 1998; IPCC, 2001; Brooks, 2003; Smit and Wandel, 2006). Scherega and Grambssh (1998) defined “adaptive actions (adaptation) are those responses or actions taken to enhance resilience of vulnerable systems, thereby reducing damages to human and natural systems from climate change and variability”. Gallopin (2006) defined that adaptation not only reduces damage, but also exploits beneficial opportunities that the climatic environment provides. Similarly, adaptation is considered to assess the degree to which it can moderate or reduce negative impacts of climate change, or realize positive effects, to avoid the danger (Smit and Wandel, 2006).

To cope with and to adapt to changes people usually set up coping/adaptation strategies that are ways in which local individuals, households, and communities have changed their mix of productive activities, and modified their community rules and institutions in response to vulnerabilities, in order to meet their livelihood needs (Rennie and Singh, 1996 in Schipper and Burton, 2009). It is noted that individual adaptation is different from government adaptation; however they are not independent of each other – they are embedded in governance processes that reflect the relationship between individuals, their capabilities and social capital, and the government (Adger and Vincent, 2005). That is why many authors conclude that an effective adaptation process would focus on the entire system rather than simply those components of the system, involve many aspects (physical, social, cultural, economic, and political environments) instead of single one (Turner et al., 2003; Brooks and Adger, 2004; Schipper, 2007). Therefore, Birkmann (2011) emphasizes that actual and potential limits of adaptation of different communities and groups need to be considered when dealing with adaptation strategies because the ability of various social groups and different coupled social-ecological systems to adapt successfully is socially differentiated. In addition, the adaptation process needs to be learnt from historical events (i.e. previous experiences) because the current vulnerability is determined by past adaptation (Brooks, 2003; Brooks and Adger, 2004). Furthermore, adaptation strategies may have potential conflicts at the same as well as different levels (Birkmann, 2011). Therefore, it is important to consider lessons learned from the past adaptation in order to build up the next adaptation strategies. Viewed in this light, Birkmann (2011) has been developing a new concept which is called first and second order adaptation. He defines first-order adaptation as those strategies and measures that households, communities, or societies develop to adapt to actual or expected climate change consequences and natural hazard phenomena. That means that first-order adaptation is adaptation to changes and thresholds in physical and ecological systems. Where as second-order adaptation encompasses processes, strategies, and measures that can and most likely need to be executed by households, communities, and societies to adjust to the direct and indirect consequences of the measures and structures implemented within the scope of first-order measures.

Within this perspective, the study tries to examine the impacts of salinity intrusion and related problems on agriculture and livelihoods of different socio-economic groups as well as to identify lessons learned from past adaptation strategies of individuals, households, communities and local government. These lessons will provide a baseline from which (and potential capacities) people will build adaptation strategies to reduce vulnerability in the future.

2.5 The socio-ecological system in sustainable development

As discussed, disaster cannot exist outside of the social and natural environment that is why Gallopin et al. (2001 in Gallopin 2006: p294) have suggested that socio-ecological system is the analytical unit for sustainable development research. A social-ecological system (SES) is defined as a system that includes societal (human) and ecological (biophysical) subsystems in mutual interaction (Gallopin 1991 in Gallopin 2006: p294). The SES is also called as coupled human-environmental system in vulnerability analysis that encompasses complex linkages between human conditions (social/human capital and endowments as population, entitlements, institutions, economic structures) and environmental conditions (natural/biophysical capital and endowments as soils, water, climate, minerals, ecosystem structure and function) (Turner et al., 2003: p8077).

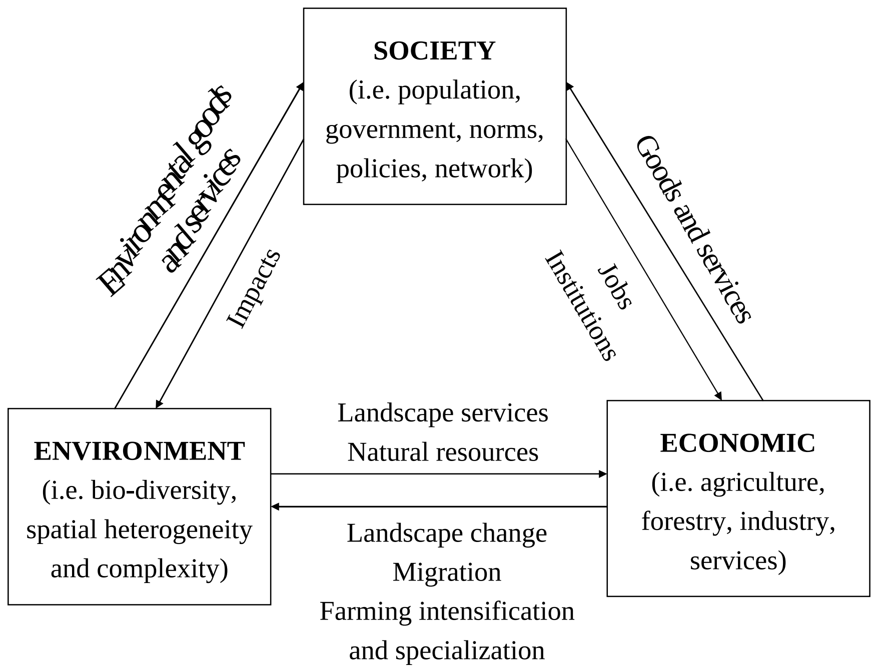


Figure 2.4: Components of the rural socio-ecological system

(Based on Schouten et al., 2009)

The social, economic and environmental spheres are three core issues that cannot be separated under sustainability as well as vulnerability analyses because of the mutuality between human beings and the environment (Birkmann, 2006 p35; Renaud, 2006: p117). For example, Figure 2.4 illustrates the relationship among three components of the complex socio-ecological system in rural areas. It shows that the society generates impacts to environment and shape economic structure, in turn the economic and environment sub-systems provide goods and services to the society. If people use natural resources in sustainable manner then the environment will not be degraded otherwise the population has to face with human-induced hazards. Mangrove forest clearing in the coastal areas of the Mekong delta can be a good example for the interaction between social, economic and ecological subsystems. Recent years, people destroyed mangrove forests for agriculture/aquaculture to provide food and income but deforestation can bring these economic activities to become risk themselves due to loss of mangrove services as food chain supply disruption, defense loss resulting in tidal flood and salinity intrusion, erosion along the coast, biochemical filter removal causing shrimp disease breakout, thus ultimately affecting people livelihood and sustainable development (Binh et al., 2005; Thu and Populus; 2006: p98).

Therefore, it is clear that the SES has dynamic and non-decomposable characteristics (Gallopin, 2006: p 294). Many of the issues related to vulnerability, resilience, and adaptive capacity belong to this aspect (Turner et al., 2003; Walker et al., 2004; Gallopin, 2006; Schouten, 2009). In other words, any analysis of vulnerability, resilience and/or adaptive capacity in context of sustainable development should be carried out under the dynamics and consideration of interactions within the socio-ecological system.

Chapter 3: RESEARCH METHODOLOGY

3.1 Steps of study

In this chapter the research methodology is described in detail. Figure 3.1 summarizes five main steps of the study. First of all, current literature related to vulnerability and adaptation is reviewed (Chapter 2). After that, the research set up is presented. The chapter is continued by depicting which data will be needed as well as how they are collected including both primary and secondary data. Finally, data analysis is provided consisting of qualitative and quantitative approaches (Chapter 3). Step 5 of the study includes results, discussions, theory reflections and outlook for future which are presented in Chapter 4 to Chapter 8.

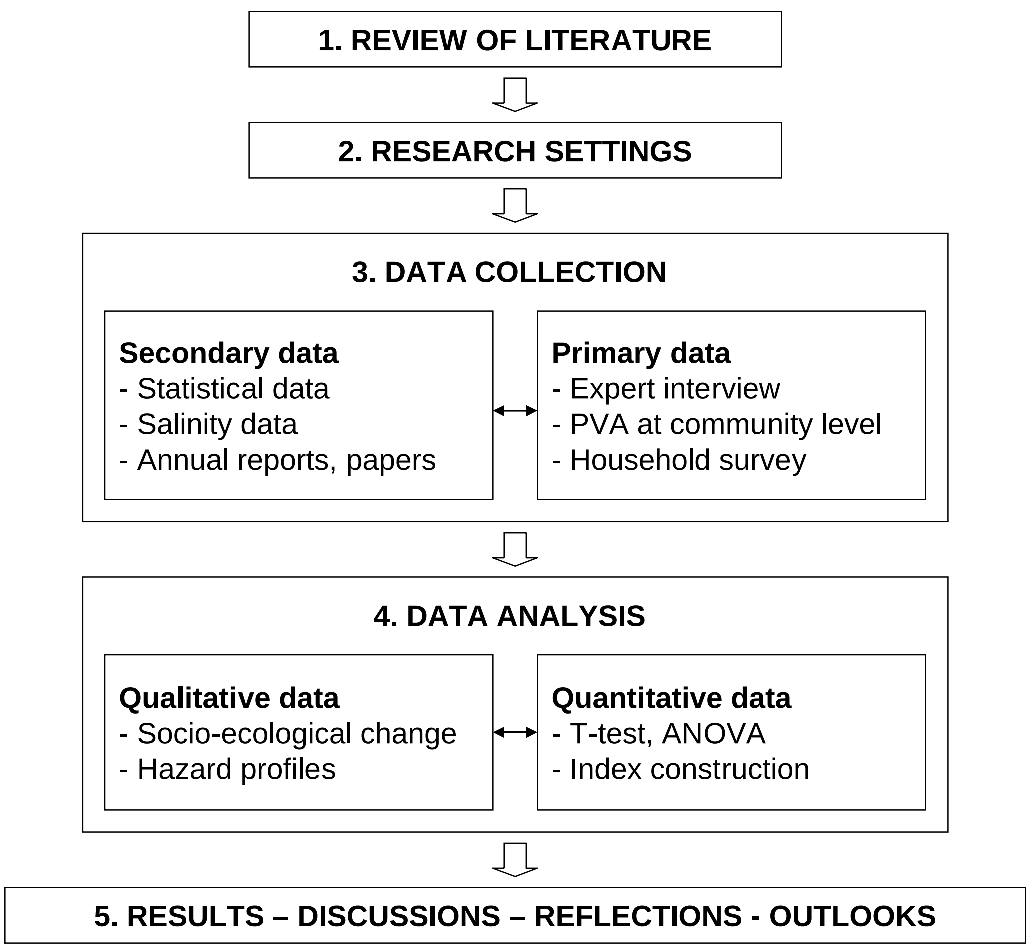


Figure 3.1: Flowchart illustrating the research methodology

3.2 Research setting

3.2.1 Framework selection

There are many conceptual frameworks for vulnerability assessment that have been employed by different scientists in different research contexts over time. The differences among such frameworks can be found in Birkmann (2006; 2013) and Füssel (2007). In this study, the BBC conceptual framework which is developed by Bogardi and Birkmann (2004) based on Cardona's work (1999 and 2001) (Birkmann, 2006) will be used. This model is modified and applied for vulnerability assessment to salinity intrusion (Figure 3.2). This framework has been used and showed many advantages (Birkmann, 2006; Birkmann et al., 2006; Fekete, 2010) such as:

- Multidisciplinary and holistic approach;
- Linkage between human beings and nature;
- Linkage between vulnerability, human security, and sustainable development;
- Problem-solving perspective;
- Time scale or dynamics of vulnerability

In this study, the key focus is vulnerability assessment. Its criteria and indicators were developed by a participatory approach during the research focusing on exposure, susceptibility and capacity of different social groups to the slow-onset hazards such as salinity intrusion and related problems based on the social, economical and environmental aspects of sustainability (Figure 3.2).

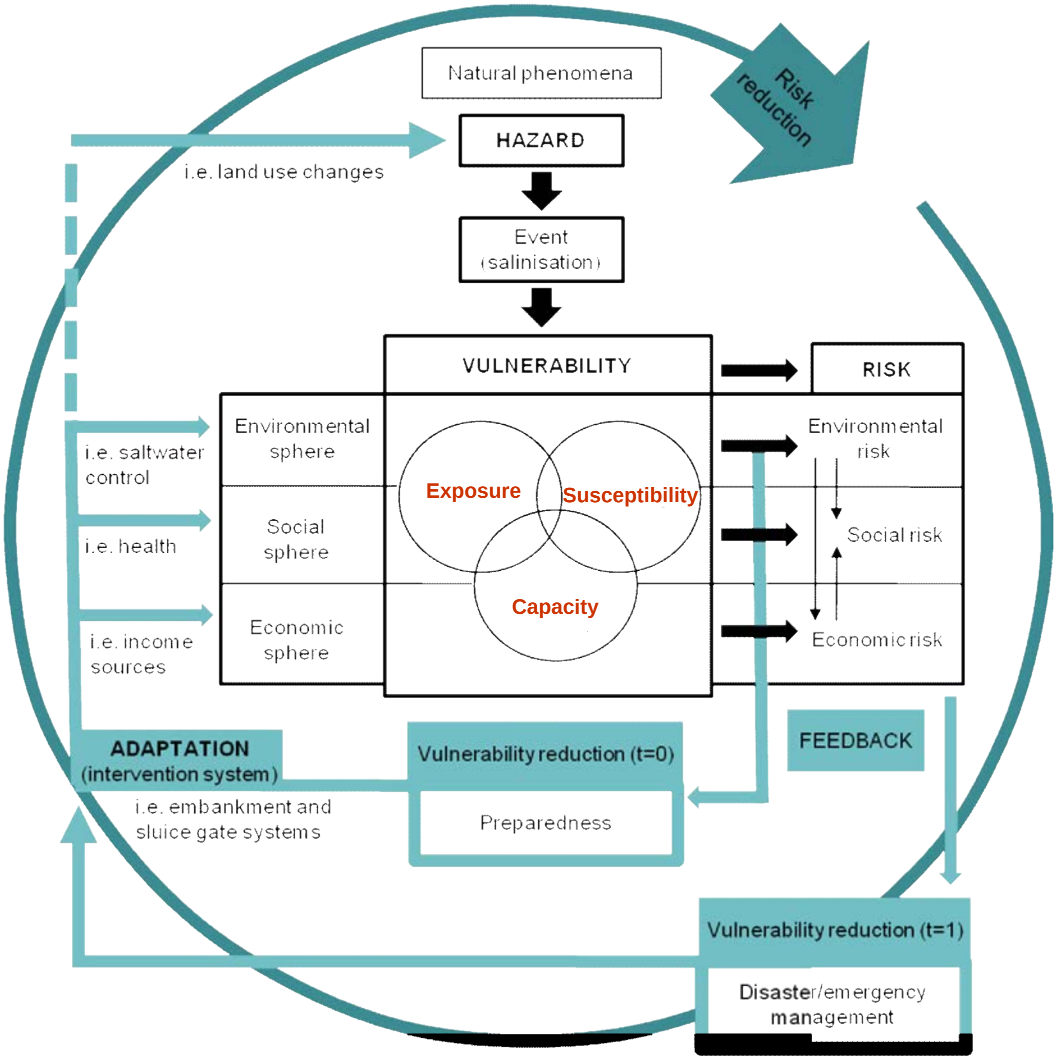


Figure 3.2: BBC conceptual framework for vulnerability and its adaptation to salinity intrusion in the Mekong delta, Vietnam

(Based on Birkmann, 2006 and Bogardi, 2009)

3.2.2 Selection of the study site

The study site was selected based on literature review and expert consultants. The main criteria guiding the selection of the study site were coastal area affected by salinity intrusion, diversified livelihood activities, various ecological zones, and different ethnic groups. After the review of current literature and consultation with professors from Can Tho university who have good knowledge and experiences on the Mekong region, the coastal province of Tra Vinh was selected. Similar approach, Tra Cu district that belongs to Tra Vinh province was chosen based on consultations with provincial experts and own field visits. The main reasons for the selection of Tra Cu district for the study are: (1) The district has been affected by salinity problems and water scarcity; (2) the district encompasses various socio-economic groups and different ethnicities (i.e. Kinh and Khmer ethnic groups, high poverty rate); (3) economic activities are diversified due to different ecological zones (i.e. freshwater zone for intensified rice farming, brackish water zone for aquaculture, sugar-cane). Therefore, data and information were collected and compared for different zones as well as different socio-economic groups. Figure 3.3 presents the study site in Tra Cu district, Tra Vinh province. Detailed information of the site will be described in Chapter 4.

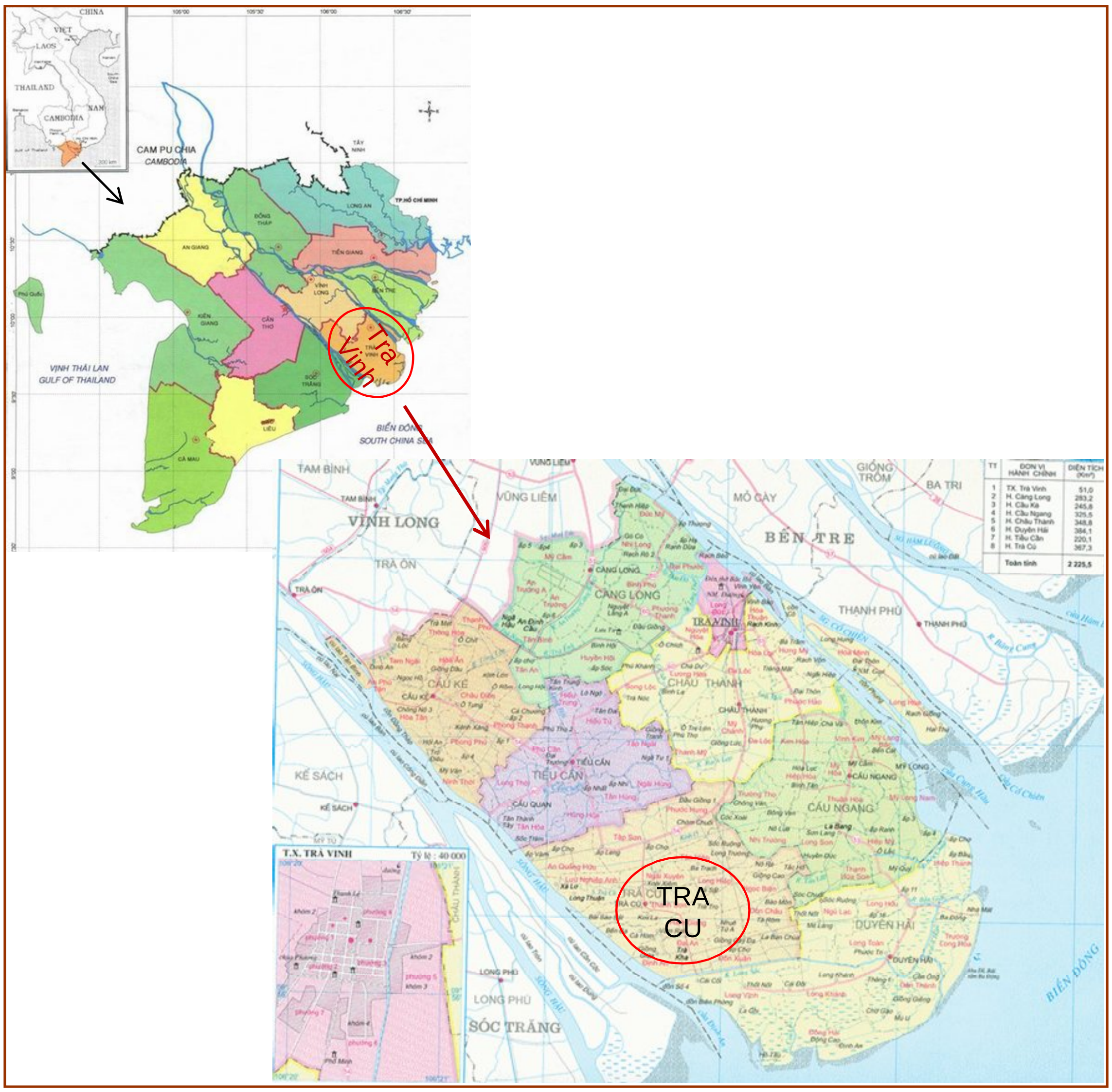


Figure 3.3: The map showing research site

3.3 Data collection

In this study a combination of quantitative and qualitative research methods was used because mixed approach provides a broader picture of the past and present vulnerabilities (see Chapter 2 for particulars of each approach). Both primary and secondary data were collected in order to answer the research questions and address the objectives. Details of primary and secondary data collection are presented as follows.

3.3.1 Primary data

A research team for primary data collection was formed. This team consists of five researchers and four MSc students of the Mekong Delta Development Research Institute (MDI), Can Tho University, Vietnam, and the author. Before the survey, the team was informed about the research objectives and data collection purposes as well as the tools used for data collection. All members in the research team were familiar with field survey methodologies. The tools for primary data collection include expert interview with local governmental staff at different levels from province to district and commune, participatory vulnerability analysis (PVA) at community level, and structured questionnaire household survey that were conducted in 2009 and 2010 as follows.

3.3.1.1 Expert interview

Expert or key informant interview is a specific form of semi-structured interview focusing on expertise in a certain field of activities (Belting, 2008). In this study, expert interview was applied firstly at provincial level to get general understandings of socio-economic conditions and details of the salinity intrusion problem as well as historical coping and adaptation strategies in Tra Vinh province. From this result, Tra Cu district was selected for the further step. At district level, the same approach was used to analyze vulnerability and adaptation to salinity intrusion and chose 4 representative communes to conduct interview at commune level. In total, 28 experts have been interviewed; of which, 6 at province, 6 at district level, and 16 in the communes (Table 3.1). Their professional knowledge includes agriculture and rural development; irrigation management, natural resources and environment; labor, invalids and social affairs; and hydrometeorology. The interview was carried out mainly one by one in face to face form and took one to one and half hour based on a checklist or semi-structured questionnaire.

Table 3.1: Distribution of expert interviews at different levels

Level	Name of location	Number of expert
Province	Tra Vinh	6
District	Tra Cu	6
Commune	Tan Hiep	5
	Kim Son	3
	Luu Nghiep Anh	4
	Dai An	4
	Total	***28***

3.3.1.2 Participatory vulnerability analysis (PVA)

After expert interview, the PVA (Participatory Vulnerability Analysis) was carried out at community level. This PVA approach is developed by ActionAid International that involves communities and other stakeholders in an in-depth examination of their vulnerability, and at the same time empowers or motivates them to take appropriate actions. The overall aim of PVA is to link disaster preparedness and response to long-term development. According to Chiwaka and Yates (2005) PVA is a qualitative way of analyzing vulnerability, which involves participation of vulnerable people themselves. The analysis helps us to understand vulnerability, its root causes and most vulnerable groups, and agree on actions by, with and to people to reduce their vulnerability. Applying PVA principle, there were 12 groups involved in the PVA process in the 4 representative communes of Tra Cu district. In each commune discussion were held with 3 groups separately including better-off, medium and poor ones. Group size ranged from 10 to 15 people considering gender and ethnic equalities. Required information and tools employed during PVA are summarized as Table 3.2. The group discussion was always carried out in the morning in the community house. In the afternoon, the research team did a transect walk and observation around the village to confirm what discussed in the morning as well as to see the levels of vulnerability and adaptation strategies to natural hazards in different social-ecological settings.

Table 3.2: Main information collected and tools employed during PVA

Step	Required information	Tools
1. Situation analysis of vulnerability	Hazard exposure: types of hazards, where, when, frequency, severity, trends, changes Who is more exposed to each hazard? Differences in vulnerability Livelihood assets and options	Timeline and trend-line Seasonal calendar Mapping Transect walk Focus group discussion
2. Analyzing causes of vulnerability	What make people vulnerable? Identification of unsafe conditions, dynamic pressures or determinants Identification of causes	Brainstorming Problem tree Ranking/prioritization
3. Analysis of community action	Understanding past coping and adaptation strategies Identification of existing resources and assets used to reduce vulnerability Any external assistance/aids?	Venn diagram Mapping Focus group discussion
4. Analysis of future adaptation strategies	Perception of future changes/threats (climate and non-climate factors) What will community do to adapt to future changes/threats? Are there any plans from local authorities? What can be done to reduce vulnerability?	Focus group discussion Scenario planning

(Based on Chiwaka and Yates 2005)

3.3.1.3 Household survey

Household survey was conducted after the PVA. A total of 512 households participated in the survey using structured questionnaire at the 4 identified communes which are representative for 3 major ecological zones in Tra Cu district. The participating households were selected randomly based on stratified sampling method that included ecological zone and ethnicity strata (Table 3.3). One household interview spent about one to two hours depending on skill of interviewer as well as responding ability of interviewee. Normally, each interviewer did 4 questionnaires per day, two in the morning and two in the afternoon. The language used in this survey was mainly Vietnamese. A small part of sample used Khmer language where the household heads could not speak Vietnamese. The results of household survey are used for vulnerability index construction and cross-checking with the PVA survey.

Table 3.3: The sample size for household survey in Tra Cu district

Strata		Number of respondents	Percentage (%)
Based on ecological zone	Zone 1 (Tan Hiep)	167	32.6
	Zone 2 (Kim Son and Luu Nghiep Anh)	172	33.6
	Zone 3 (Dai An)	173	33.8
	Total	*512*	*100.0*
Based on ethnicity	Kinh (also called Vietnamese)	237	46.3
	Khmer	275	53.7
	Total	*512*	*100.0*

3.3.2 Secondary data

The secondary data regarding to the social-ecological system conditions and changes in the study site were gathered from different sources and organizations as follows:

- Annual report from provincial, district, and commune levels were collected at the People Committees to understand general socio-economic development in the research site during the last 5 years.
- Secondary data related to population, poverty rate, land use, agricultural and fish production as well as weather information in the study areas was mainly obtained from national statistical books and provincial/district statistical organizations. These data and information help to analyze transformation process in the coastal area consisting of social, economical and environmental aspects.
- Data and information related to agriculture and crop damages due to salinity intrusion were collected from the Department of Agriculture and Rural Development at province and district levels. Such data provide useful understanding of agricultural development process and its relation to salinity risks due to the “creeping” characteristic of this hazard.
- Salinity concentration data at 4 gauging stations along Tien and Hau rivers were gathered from the Center of Hydrometeorology in Tra Vinh province to analyze the salinity trend during the period of 1995-2010 in order to have better understanding of past and present changes of this slow-onset hazard.

3.4 Data analysis

3.4.1 Qualitative data from PVA

The qualitative information and data from the expert interview and PVA survey were analyzed via an inductive approach as described by Thomas, 2003. Firstly, the extensive and raw data were condensed into a brief and categorized into different categories. Secondly, they were selected corresponding to research objectives. Finally, the findings were documented and discussed in a logical and suitable way. Following the above steps, the findings in this study were grouped into the three components of vulnerability such as hazard exposure, susceptibility and capacity in different ecological zones at the study areas.

3.4.2 Salinity data

Salinity data collected from the Center of Hydrometeorology in Tra Vinh were coded, and entered in Microsoft Excel. Excel and SPSS were used for data analysis. Descriptive statistics as mean, maximum and minimum values of salinity concentration were used to analyze trends of salinity level during the period of 1995-2010 at 4 gauging station along Tien and Hau Rivers. Such data were presented monthly and annually. Besides, a t-test was applied to compare mean of salinity concentration between 2 sub-periods; for example, 1995-2002 and 2003-2010 in order to investigate salinity level changes.

3.4.3 Vulnerability index construction

The results of household survey are used for vulnerability index construction. The vulnerability index was constructed based on three major elements as exposure, susceptibility, and capacity sub-indexes. By this approach, total vulnerability to salinity intrusion will be measured and compared in different contexts such as ecological zones and ethnic groups. Details of index development are presented in Chapter 7.

3.5 Research obstacles

3.5.1 Limitations of research team

Of course, all stages of the research particularly during empirical primary data collection phase were not conducted by the author. Therefore, a research team were formed consisting of researchers and master students at the Mekong Delta Development Research Institute to support the interview action. Despite their knowledge and expertise working in the Mekong region, there were still some limitations. First, they have different education backgrounds and levels that cause difficulty to get detailed understanding of research settings, especially a new concept like vulnerability. Second, even when the team members were familiar with some participatory tools, and household surveys. The PVA approach was totally new to them. To deal with this situation, experienced people were invited. In addition, before going to the field, one meeting was organized to explain the purpose of study and to train all members how to use different participatory techniques when assessing vulnerability of communities. Later on, another training was conducted to show them the household questionnaire and the way to gather data in order to have a common understanding, then homogenous set of data. Fortunately, the above strategies worked well and increased the team capacity.

3.5.2 Access to and qualities of secondary data

In this study, secondary data were collected for different aspects and from various sources as well as departments. Accessing to such data was not always easy. Most cases, a formal research permission from the local university – like Can Tho university was needed. All required data must be identified and the reasons for collecting had to be explained prior collecting data. However, in some cases it did not work, especially “sensitive” data; for example, salinity level, land use map, crop damages, etc. Another problem, the same data may be stored at different governmental departments due to the fact that institutional arrangement changes time by time; therefore, it had to contact many people to gather data sets, especially in case of long-term data to investigate the changes of socio-ecological systems. Besides, all data and documents were stored on paper (not electronic files) then they could be lost easily resulting lack of some years in a series. Furthermore, the quality of secondary data can also be seen as a paramount challenge. First, data inconsistence can be found in many cases by different departments or even within the same department in different years of publications. Second, some secondary data had been published for “political” purposes rather than reflecting the real situation of society; for example, poverty rate, income per capita, crop loss, etc. Third, all secondary data were recorded according to administrative boundaries, therefore it was difficult to analyze them according to socio-ecological zones. Fourth, data for crop damages by hazards in general and salinity intrusion in particular were not recorded crop by crop and year by year, except for rice farming. Hence, to collect all data needed, it was necessary to make use of not only official letters but also “informal” way through the existing networks of the author. To fill the gap between current secondary data and the reality, many approaches had been applied; for example, triangulation checking with different sources, expert consultation, and field observations.

3.5.3 Difficulties of discussing sensitive topics

The political system in Vietnam is still controlled tightly that can affect discussion on “sensitive topics” like ethnicity issues or vulnerable conditions of local people or assessment of governmental adaptation policies. This problem happened both at community level as well as expert interviews in different levels of governmental administration. In many cases, the people did not answer questions that are perceived as politically sensitive issues in general and particularly when asking about vulnerability of the Khmer group. In such situations, the questions should be adjusted in other directions to encourage people to talk freely. Or the issues can be addressed in depth-interviews with selected people who are ready to share their ideas individually.

3.5.4 Language barrier

While most conversations were conducted in Vietnamese, however language barrier especially with Khmer people in remote communities was faced. It is necessary to note that this problem did not only cause difficulties in communication but also encouragement of people participation during the PVA survey. Luckily, in the research team there were two persons who spoke Khmer as their native language. Therefore, when the team talked with Khmer groups these persons acted as facilitators.

3.5.5 Challenges to select interviewees

There were challenges to select interviewees including experts and households. For expert interview, it was not easy to meet “right” persons for interviewing due to the fact that the appointment was made with certain governmental organization and did not know whom to talk. In most cases, the interviewer had to come back again in order to meet “true experts”. This was not only time-consuming but also increase cost. For household survey, the households were chosen randomly based on household lists from the villages, however, there were some constraints. First, the heads of villages might not agree with selected lists. They often suggested people who would provide “good” information for government, or their relatives, or households closed to road for easy transportation. Therefore, it was important to convince them and try to minimize selection bias. Second, the selected households were left or absent. In this case, the interviewers had to go back again. If the households were still absent, they were replaced by others who had the same "characteristics". Third, the survey always targeted household heads, but in some situations household heads were not at home. Then, the interviewers asked persons who had right to make decision in their families.

In short, there were some challenges and problems during this phase of the research. Most cases, they were recognized and solution were found for minimizing their impacts. Therefore, study results can still reflect the true context despite the above outlined obstacles.

Chapter 4: RESEARCH CONTEXTS: HAZARD, SOCIAL-ECOLOGICAL CONDITIONS AND CHANGES

This chapter provides basic information to understand research contexts from the national to local level. The chapter begins with general introduction of the main natural hazards in Vietnam. It continues by presenting conditions and changes of social-ecological systems in the Mekong delta, especially in the coastal regions considering agricultural sectors and rural livelihoods. At the end of the chapter, the study site conditions where data were collected are described in details for the better understanding of the vulnerability analysis in the next chapters.

4.1 Natural hazards in Vietnam

Vietnam is a country in transition. It is located in Southeast Asia. To the North it borders with China, to the East with the Gulf of Tonkin, to the West with Laos and Cambodia, to the Southeast with the East Sea and to the Southwest with the Gulf of Thailand (Figure 4.1).

Figure 4.1: Map of Vietnam showing different hazards across the country

(Source: Oxfam, 2008)

Its geographic position and topographic conditions (long coastline, from narrow and low plains to steep and high mountains) result in serious and diversified natural hazards. Among them, a high relative frequency of disaster hazards includes flood, typhoon, inundation, erosion and sea water intrusion (Table 4.1). The hazards often occur throughout the country from the north to the south as indicated in Figure 4.1; salinity intrusion and drought seem to increase in the coastal areas of the Mekong delta (Sam, 2006; Binh, 2010; Birkmann et al., 2012). Many authors revealed that Vietnam is one of the most disaster-prone countries in the world and also situated at one of the biggest typhoon centers of our planet, the East Sea (Few et al., 2006; Ninh, 2007; SRV, 2007). According to UNDP, over 70% of Vietnam's population is at risk from typhoons, floods, storm surges, flash floods, landslides, or mudflows. National report on disaster reduction (2004) showed that natural disasters from 1994 to 2003 killed 7,537 people; 395,202 houses collapsed; 4.7 million ha rice fields and 65,955 ha aquaculture ponds submerged; and 11,764 ships have been damaged. It was estimated that total damages caused by natural disasters in Vietnam were about VND 75,000 billion (approximately EUR 3.0 billion) between 2002 and 2006 which is equal to 1.5% of GDP per year (SRV, 2007).

Table 4.1: Relative frequency of disaster hazards in Vietnam

High	Medium	Low
Flood	Hail and rain	Earthquake
Typhoon	Drought	Technological accident
Inundation	Landslide	Frost
Erosion/silting	Fire	
Sea water intrusion	Deforestation	

Moreover, with 3,260 kilometers coastline and low topography, Vietnam has been considered as being one of vulnerable areas in the world that will be most affected by climate change and sea level rise (SLR) in which the Mekong delta is identified to have the worst impacts (Dasgupta et al., 2007; Carew-Reid, 2008; MONRE, 2012; USGS, 2010). The Ministry of Natural Resources and Environment reported that average temperature has increased 0.5^{o}C over the past 50 years and sea level has risen 2.8 mm per year (MONRE, 2012). Carew-Reid (2008) predicted that 4.4% of land areas and 10.0% of total population would be impacted by one meter SLR in Vietnam. In term of capital effect, it is estimated that USD 17 billion will be lost by annual flooding with one meter

SLR, which is about 80% of the annual GDP of the whole country (Carew-Reid, 2008). Therefore, coping with and adaptation to natural hazards including SLR are the most serious challenges for the development of the country in the future.

4.2 Social-ecological conditions and changes in the Mekong delta

4.2.1 Physical environment

The Mekong delta is located in the south of Vietnam including 13 provinces; of which, 8 provinces have a border with the coast, namely Long An, Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau, and Kien Giang. Therefore, when people mention the coastal areas of Mekong delta they refer to these 8 provinces (Sam, 2006). The Mekong delta covers an area of around 4.0 million ha with nearly 3.0 million ha of agricultural, forestry and aquaculture land (about 75% of its total land) and is known as one of the most productive and intensively cultivated agricultural areas in all of Asia (Hook et al., 2003; CTSO, 2010). It is characterized as fertile alluvial flat plain with a tropical monsoon climate. Land elevation ranges between 0.3 to 4.0 m above mean sea level, of which 60% lies below one meter (Hoi, 2005). Average temperature is about 27.5^{o}C. There are two separate seasons in the delta, the dry and wet. The dry season begins in December and ends in April while the wet with heavy rainfall is between May and November (De, 2006). The mean annual rainfall is 1,733 mm, of which more than 80% falls in the wet season (SIHYMATE, 2010). The delta hydraulics is complicated because of its canal/river networks and influenced by the Mekong river flow and two tidal regimes: the diurnal tidal movement of the East Sea and the semi-diurnal tidal movement of the Gulf of Thailand (Sanh et al., 1998; De, 2006). Due to both the overflow from the Mekong River and heavy local rainfall, a large part of the northern delta is inundated in the wet season (Hoi, 2005; Tuan et al., 2007). However, in the dry season, the low discharge of the Mekong River keeps water table down from the field level and causes water shortage in the whole delta (De, 2006; Tuan et al., 2007). Besides low river flow, overuse of water for irrigation and hydropower projects in upstream area cause serious salinity intrusion and drought in the downstream region (White, 2002; Nhan et al., 2007).

4.2.2 Socio-economic conditions and changes

As "rice-bowl" of Vietnam, the Mekong delta plays a very important role in socio-economic development and is the key area for national food security strategy. The population of the delta reached 17.4 million inhabitants in 2012, of which about 13.1 million or 75% of the population live in rural areas and mainly obtain their livelihood from agricultural, forestry and fishing activities (GSO, 2013). In 2012, with 4.18 million ha planted area of rice (from single to triple crops per year) the delta produced 24.3 million tons accounting for 56% of national rice production. For aquaculture, it contributed more than 71% of country aquaculture production in 2012 (GSO, 2013). According to the National Survey on Agriculture, Rural Development and Fishery in 2011, the structure of delta's economy has been changed towards reducing agricultural while increasing industrial activities, construction and services (GSO, 2011b). Table 4.2 shows that the percentage of agricultural households has been declined from 73.1 to 65.5% between 2006 and 2011 while industrial and construction sectors increased from 8.4 to 12.2% and services from 16.6 to 19.9% in the same period.

Table 4.2: Changes of economic activities of households in the Mekong delta between 2006 and 2011

	Number of households		**Structure (%)**	
Sectors	**2006**	**2011**	**2006**	**2011**
Agriculture	2,211,735	2,179,678	73.1	65.5
Industries and constructions	255,415	407,528	8.4	12.2
Services	502,800	663,636	16.6	19.9
Others	55,378	77,481	1.8	2.3
Total	*3,025,328*	*3,328,323*	*100.0*	*100.0*

(Own calculation based on GSO, 2011b)

However, the delta economy is still below the national average dominated by the agricultural sector as its contributions is about 40.1% of total GDP in 2010 whereas this figure is only 20.6% at national level (AGSO, 2011). The National Survey on Living Standard reported that an average income per capita in the delta was VND 21.4 million in 2012 (around USD 1,000) compared to VND 24.0 million at country level (GSO, 2013).

4.2.3 Land use changes and aquaculture development

Land use has been changing in the Mekong delta during the last decades. As shown in Table 4.3, agricultural and forestry land decreased 369,900 and 33,100 ha respectively in the period of 2000 to 2012; while homestead area increased 21,200 ha and other land (industry, infrastructure, etc) increased 465,900 ha. The agricultural land has been reduced because of socio-economic development. The General Statistics Office reported that the population in the Mekong delta grew up from 16.3 to 17.4 million inhabitants between 2000 and 2012 requested more areas for housing and infrastructure constructions (GSO, 2002; 2013). Besides, many industrial zones have been built based on rice fields; for example, industrial and construction sectors have the highest annual growth rate in the past 10 years as their values increased about 1.56 times from VND 29,876 billion to 46,651 billion (CTSO, 2010; AGSO, 2011).

Table 4.3: Land use changes in the Mekong delta between 2000 and 2012

Land use (in 1000 ha)	Years		Changes (2000 – 2012)	
	2000	**2012**	**Quantity**	**Percentage**
Agricultural land	2,970.2	2,600.3	-369.9	-12.5
Forestry land	337.8	304.7	-33.1	-9.8
Homestead land	101.2	122.4	21.2	20.9
Others	562.1	1028.0	465.9	82.9
Total area	***3,971.3***	***4,055.4***	***84.1***	***2.1***

(Own calculation based on GSO, 2002; 2013)

On the other hand, large areas of rice fields and mangroves have been replaced by aquaculture ponds mainly in the coastal regions. Due to high profits from shrimp farming and corresponding governmental policies thousands of hectares of traditional rice fields in coastal provinces have been converted to shrimp ponds (Binh, 2009). A big jump in this process was between 2000 and 2004 as the growth rate of water surface for aquaculture in the coastal areas of the Mekong delta reached 15.4% annually while this figure was only 3.6% in the previous period (1995 – 1999) and 1.3% in the recent years (2005 – 2012) (Figure 4.2). This change results in the increase of aquaculture production, importantly shrimp products. The statistical data reported that shrimp production in Vietnam increased from 55.316 tons in 1995 to 473.861 tons in 2012, of which about 80% comes from the eight coastal provinces of the Mekong delta (GSO, 2000; 2002; 2005; 2013).

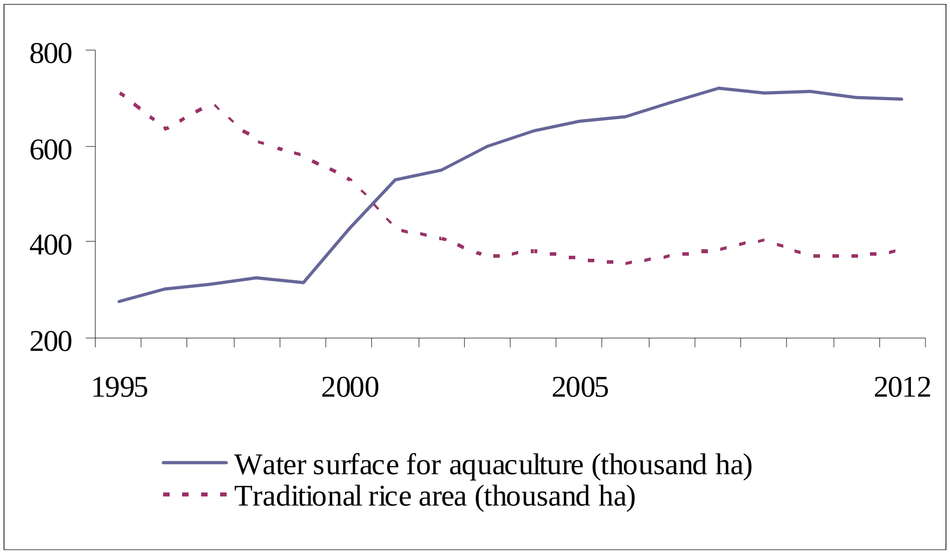


Figure 4.2: Change of water surface for aquaculture and traditional rice area in the coastal regions of the Mekong delta

(Own figure based on GSO, 2000; 2002; 2005; 2013)

4.2.4 Dyke developments for rice intensification

Dyke buildings for rice intensification are key element of economic development in the Mekong delta particularly for rural areas. Back to the early 1980s, Vietnam had to import rice for domestic consumption. In order to secure food and increase livelihoods for people, the government focused on "rice first policy" by improvements of irrigation infrastructure through dyke developments from different financial investment sources, importantly the international funds like World Bank and ADB. In the Mekong delta, many dyke systems have been developed since 1990s to control floods in the upper parts and salinity intrusion in the coastal regions (Table 4.4).

Table 4.4: Main flood and salinity control projects in the Mekong Delta

Flood control projects		**Salinity control projects**	
Project name	**Location**	**Project name**	**Location**
Long Xuyen Quadrangle	An Giang and Kien Giang	Tam Phuong water control project	Tra Vinh
North Vam Nao	An Giang	South Mang Thit	Tra Vinh and Vinh Long
Plain of Reeds	Dong Thap and Long An	Tiep Nhat	Soc Trang
Western Bassac River area	Kien Giang, Ca Mau	Quan Lo – Phung Hiep	Hau Giang, Bac Lieu, Ca Mau
O Mon – Xa No	Can Tho and Hau Giang	Ba Lai Dam	Ben Tre
		Go Cong	Tien Giang

Thanks to these dyke projects, the irrigated areas in the Mekong delta increased rapidly from 52% in 1990 to 91% of cropland in 2002 that provides good condition for agricultural intensification as farmers can grow 2 to 3 rice crops per year even in the coastal regions (Ut and Kajisa, 2006). As results, rice planted area, production and yield in the delta have grown up remarkably. Figure 4.3 indicates that rice planted area does not increase in the period of 1976-1986 but increases very fast from 2.3 million ha in 1987 to 3.9 million ha in 2000 and 4.1 million ha in 2011. Similarly, rice production grow 3.6 times from 6.4 million tons to 23.2 million tons between 1987 and 2011.

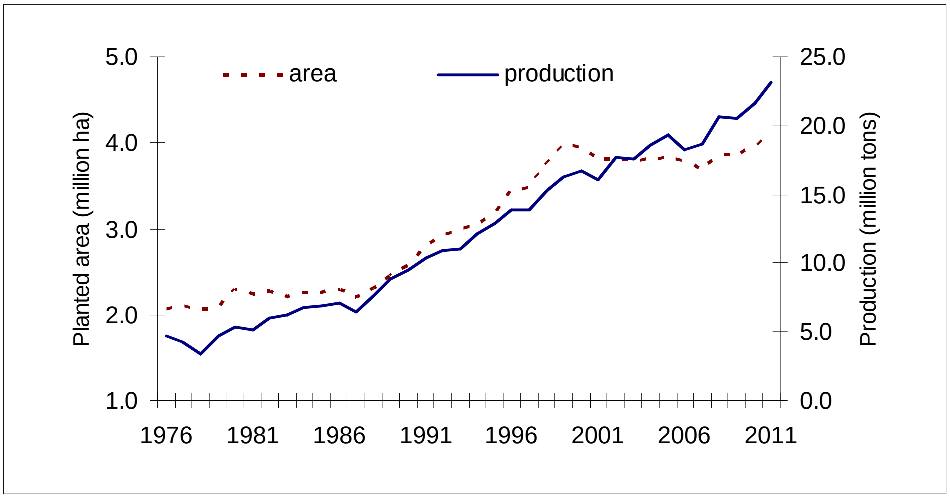


Figure 4.3: Rice development in the Mekong delta

(Based on GSO, 2000; 2002; 2005; 2013)

Rice yield also have the same trend as planted area and production. Table 4.5 depicts that rice yield in the Mekong delta increases from 2.3 tons per ha in 1976 to 5.7 tons per ha in 2011. This improvement is even better than comparing to country and world level. In short, water management for agriculture development in the Mekong delta has received excellent results that make the country shifting from rice importer in 1980s becomes one of the biggest rice exporters nowadays.

Table 4.5: Comparison of rice yield growth (tons per ha)

	1976	1985	1990	1995	2000	2005	2011
World (average)	2.5	3.3	3.5	3.7	3.9	4.1	4.4
Vietnam	2.2	2.8	3.2	3.7	4.2	4.9	5.5
Mekong delta	2.3	3.0	3.7	4.0	4.2	5.0	5.7

(Based on FAO data, GSO data)

4.2.5 Livelihood changes

Thanks to agricultural development (as shown in the above analysis) people livelihoods in the Mekong delta have achieved remarkable improvement recently. According to the Household Living Standard Survey in 2010, 73% of households reported that their livelihoods are better compared to 2006 (GSO, 2011c). The GSO (2013) showed that monthly income per capita increased 4.8 times from VND 371.300 to 1.785.000 between 2002 and 2012 in the Mekong delta but this improvement does not keep up with country level as shown in Figure 4.4. The incidence of poverty in the Mekong delta is still high when compared to other regions like the Red River delta or South East of Vietnam. There was 10.6% of population (1.8 million inhabitants) living below the Vietnamese poverty line[1] in 2012 in the Mekong delta while the corresponding figures were 6.1% in the Red River delta and 1.4% in the South East regions (GSO, 2013). Besides, the gap between the poor and better-off groups in the Mekong delta becomes bigger year after year as the income difference between group 1 and group 5 increased from 6.8 times in 2002 to 7.4 times in 2010 and this trend seems to be higher in the coastal provinces (GSO, 2011c). Moreover, income gap and poverty related issues also can be found among ethnic groups; for example, the poverty rate is often high in Khmer communities one of the minority ethnicities in the delta (Binh, 2011; GSO, 2011c). Therefore, poverty reduction and equal income distribution are some of the key issues for social sustainable development in the Mekong delta.

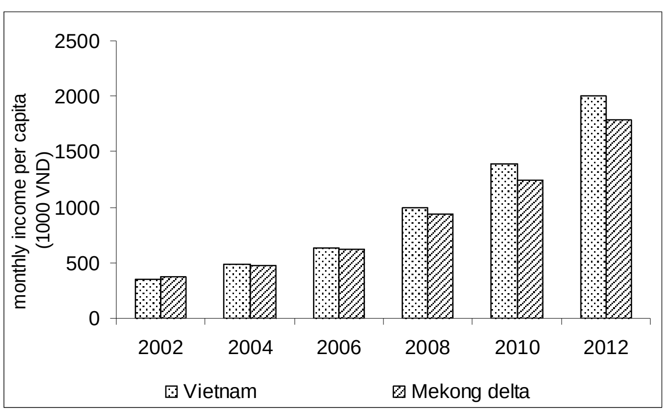


Figure 4.4: A comparison of income changes in the Mekong delta and Vietnam

(Based on GSO, 2013)

[1] In the rural area, households with average income under VND 6.36 million per capita per year are regarded as poor households; similarly, it is VND 7.92 million in the urban case (GSO, 2013).

4.2.6 Water related problems

Within the Vietnamese territory, the Mekong river splits into nine main branches that make very fertile soils for attractive agricultural conditions and very easily accessible for waterborne transportation by a dense network of canals and rivers (Hook et al., 2003). It is also helpful for the development of irrigation systems in the delta during the last 30 years. However, the delta has to face conflicts between socio-economic growth and sustainable development (White, 2002). The most serious water related problems could be recognized as follows:

Water pollution: Agriculture and aquaculture have changed from extensive to intensive (for example, rice cultivation from one crop to two or three crops per year) contributing to GDP development and better income for farmers. However, intensive rice farming has caused water pollution due to chemical fertilizers, pesticides, herbicides, and fungicides. Nhan et al. (2002) reported that wild fish in rice fields and rivers/canals has been declining noticeably in the delta. Development of aquaculture also has a part in water pollution because of feed and chemical uses (Nhan et al., 2007; Tam et al., 2008). Recently, shrimp germs in water sources have been considered as a big challenge for shrimp disease control. In addition, industrial and domestic wastes are mainly untreated before being discharged into the recipient water bodies (Tuan et al., 2007; Loan, 2010).

Floods: As mentioned, each year a large area in the delta is inundated. About 1.2 – 1.9 million ha in the region is under annual flood (Tuan et al., 2007). Here, floods have low discharge capacity but cause prolonged deep inundation, river bank erosion, and transport failure (SRV, 2007). In recent years, high floods have occurred frequently in the delta. Particularly, flooding in 2000 killed 481 people and caused an economic loss of nearly VND 4,000 billion or USD 0.25 billion (SRV, 2004).

Salinity intrusion: Salinity intrusion is a severe natural phenomenon in the Mekong coastal areas. Due to low river flow and the tidal influence in the dry season, seawater can reach 40 – 60 km upstream inland (Miller, 2003). As result, about 2.1 million ha are affected by salinity problem (Sam, 2006). Recently, salinity intrusion is recognized as an emerging hazard for socio-economic development in the delta due to the fact that it has been increasing in terms of intensity and frequency.

Fresh water shortage: Fresh water shortage usually occurs in the coastal provinces. The total area affected by fresh water shortage in the delta is about 2.0 million ha (Truong and Anh, 2002). The shortage of fresh water in the dry season affects not only on agricultural and livestock husbandry activities but also livelihoods and health of people (Nhan et al., 2008).

River flow alternation: Due to its location, the Mekong delta of Vietnam is highly vulnerable to any changes from upstream development. Before 1990 in the Mekong River Basin had only one hydropower plant, namely Nam Ngum in Laos but in 2010 there were 12 active reservoirs for hydropower purposes with a total active volume up to 15.77 km^3 (DWRPIS, 2011). Besides, many irrigation projects have been constructed and hundreds of dams have been planned in the basin (MRC, 2011). Theoretically, the upstream reservoirs will increase downstream flow in the dry season however critical situations will occur in extremely dry years when reservoir water shortages may reduce reservoir releases. Under such conditions, the downstream flow regime would be significantly affected (DWRPIS, 2011). Furthermore, the operation of upstream reservoirs can negatively influence the natural regime of Tonle Sap and the lower Mekong river.

4.2.7 Climate changes and sea level rise

Temperature: The meteorological data showed that average temperature in the south of Vietnam (including Mekong delta) for 1991 to 2000 was higher than the average for 1931 – 1940 by 0.6^{o}C and in 2007 higher than the average for 1991 – 2000 by 0.4 – 0.5^{o}C. It is projected that with medium emission scenario (B2) the annual temperature in the south can increase 0.4, 1.0 and 2.0^{o}C in the year 2020, 2050 and 2100 respectively comparing to the period of 1980 – 1999 (MONRE, 2009).

Rainfall: In the south, rainfall will increase by 1.0, 1.5 and 1.9% in 2100 relative to the period of 1980 – 1999 with low, medium and high emission scenarios respectively. However, its distribution throughout the year will change towards negative impacts on people. Table 4.6 presents that in the dry season (December to May) the rainfall will decrease while increase in the wet period (June to November). It will cause more drought and freshwater shortage in the dry but inundation in the wet season resulting in higher risk for agriculture and aquaculture.

Table 4.6: Rainfall change (%) in the south of Vietnam, relative to the period of 1980 – 1999 with medium scenario (B2)

Months	2020	2050	2100
December – February	- 3.0	- 8.1	- 15.4
March – May	- 2.8	- 7.5	- 14.3
June – August	0.3	0.9	1.6
September – November	2.6	6.8	13.0
Whole year	***0.3***	***0.8***	***1.5***

(MONRE, 2009)

Typhoons: Typhoon is one of the major and dangerous types of natural hazards in Vietnam and tends to increase in term of intensity and frequency. It is estimated that 80 – 90% of the country population is affected by typhoons (MONRE, 2009). In the past, most of typhoons hit the northern and central parts of Vietnam but they have been moving southward and caused heavy damages. For example, the Linda typhoon in November 1997 occurred in the Mekong delta and killed 411 people with total damages was estimated up to VND 6.214 billion or 2.7% of country GDP at that time (Binh, 2011; GSO, 1999).

Sea level rise: Sea level has been rising in Vietnam at a rate of 3 mm annually in the period of 1993 – 2008 which is nearly equal to the worldwide records (SIHYMETE, 2010). Data from Hon Dau tidal gauge in the north showed that sea level increased 20 cm during the past 50 years (MONRE, 2009). In the Mekong delta, SLR from 9 to 13 cm has been recorded along estuary stations during the 1980 – 2007 (SIHYMETE, 2010). The Ministry of Natural Resources and Environment has proposed 3 SLR scenarios for Vietnam with the low (B1), medium (B2) and high (A1F1) emission levels. The results show that, in 2050 sea level may climb about 20 to 33 cm and by the end of 21st century it may increase about 65 to 100 cm compared to the period of 1980 – 1999 (Table 4.7).

Table 4.7: Projection of sea level rise (cm) in Vietnam, relative to period of 1980 - 1999

Scenarios	2020	2050	2100
Low emission (B1)	11	28	65
Medium emission (B2)	12	30	75
High emission (A1F1)	12	33	100

(MONRE, 2009)

As mentioned, Vietnam in general and the Mekong delta in particular will be the most vulnerable areas to the SLR. According to Carew-Reid (2008) with 100 cm the rise of sea level, the inundated areas will cover around 14,528 km^2 of Vietnam total land, of which 85% in the Mekong delta. MONRE (2009) projected that with the low, medium and high emission scenarios by the end of the year 2100 the inundated areas of the Mekong delta will be 5,133; 7,580 and 15,116 km^2 or 12.8, 19.0 and 37.8% of the delta areas (Table 4.8).

Table 4.8: Inundated areas of the Mekong delta by 2010 with different sea level rise scenarios

Scenarios	Sea level rise (cm)	Inundated areas (km^2)	Percent of inundated
Low emission (B1)	65	5,133	12.8
Medium emission (B2)	75	7,580	19.0
High emission (A1F1)	100	15,116	37.8

(MONRE, 2009)

In short, climate change and sea level rise have been occurring especially in the coastal regions of the Mekong delta. Their impacts include soil salinization, lack of freshwater for domestic and agricultural uses, land loss due to erosion and inundation, productivity reduction, coastal ecosystem degradation, increase of production cost, and livelihood threats (Wassmann et al., 2004; Hanh and Furukawa, 2007; SIHYMETE, 2010).

4.3 Description of the study sites from province to commune level

The research was carried out in Tra Cu district, Tra Vinh province that belongs to coastal area of the Mekong Delta, Vietnam (Figure 3.3). The province covers an area of 2,341 km^2, of which about 26.6% saline soil which can be found easily in Tra Cu district (TV-DARD, 2004; TVSO, 2008). Crossing the coastal line and under the context of sea level rise, Tra Vinh would be affected at highest degree. Carew-Reid (2008) projected that around 45.7% of province area would be inundated (the third highest loss for a province in Vietnam) by 1 m sea level rise in the year 2100. Recently, many embankment systems have been invested in this region to control sea water; however, such interventions are not usually successful (Tuan et al, 2007; Nhan et al., 2008). Total population of Tra Vinh was 1.0 million inhabitants, of which 30% Khmer people who is considered as minority ethnic group in the Vietnamese Mekong delta (De, 2006; TVSO, 2013). More than 80% of population live in rural area and rely on small scale agriculture (TVSO, 2008). In term of economic development, Tra Vinh is one of the poorest provinces in the country. According to the Survey on Household Living Standards in 2010, its general poverty rate was 23.2% that is the highest level in the delta (GSO, 2011c). Therefore, Tra Vinh is a suitable place for studying vulnerability and adaptation to salinity intrusion.

The main reasons for the selection of Tra Cu district for the study are: (1) The district has been affected by salinity problems and water scarcity; (2) the district encompasses various socio-economic groups and different ethnicities (i.e. Kinh and Khmer ethnic groups, high poverty rate); (3) economic activities are diversified due to different ecological zones (i.e. freshwater zone for intensified rice farming, brackish water zone for aquaculture, sugar-canes). Therefore, data and information were collected and compared for different zones as well as different socio-economic groups. Table 4.9 presents profile of Tra Cu district in comparison with Tra Vinh province. It shows that Tra Cu district can be as "representative" study site because of many similar things comparing to Tra Vinh province. Total land area in the district is 36,992 ha, approximately 16.5% of province. Likewise, the share of total population, rice sown area, cattle, pig, and poultry stock occupy more or less the same as 16%.

Table 4.9: Characteristics of research site at provincial and district level, data as in 2011

Category	Tra Vinh province	Tra Cu district	Percentage of Tra Cu over Tra Vinh (%)
Total area (ha)	234,116	36,992	16.5
Rice sown area (ha)	233,020	44,180	17.6
Sugar cane area (ha)	6,569	4,850	69.2
Aquaculture area (ha)	29,163	2,192	7.9
Cattle (head)	150,110	35,070	20.4
Pig (head)	430,240	55,010	15.9
Poultry (head)	6,374,080	1,195,320	17.6
Total population (inhabitant)	1,012,100	177,300	15.9
- Kinh (%)	69.0	37.2	9.1
- Khmer (%)	30.0	62.1	31.9
- Chinese and others (%)	1.0	0.7	9.0
General poverty rate (%)	20.1	33.2	---

(Based on TVSO, 2012; TCSO, 2012)

At community level, Tan Hiep, Kim Son, Luu Nghiep Anh and Dai An communes in Tra Cu district were selected for primary data collection to assess vulnerability to salinity intrusion. Characteristics of these four representative communes are described in Table 4.10. The four communes are located in 3 different social-ecological conditions. Tan Hiep belongs to freshwater zone suitable for intensive rice farming. Kim Son and Luu Nghiep Anh are characterized by sugar cane cultivation. While Dai An closed to the coast and affected by salinity intrusion where integrated rice-shrimp farming system is common.

Table 4.10: Characteristics of 4 representative communes in Tra Cu district, data as in 2011

Category	Tan Hiep	Kim Son	Luu Nghiep Anh	Dai An
Total area (ha)	2,337	2,228	2,869	1,253
Total population (inhabitant)	9,975	8,546	13,249	10,517
Khmer population (%)	83.2	91.7	41.4	74.5
General poverty rate (%)	41.4	33.1	12.1	24.5
Rice sown area (ha)	4,636	374	165	941
Sugar cane area (ha)	8	1272	1827	21
Aquaculture area (ha)	21.4	34.1	50.7	273.8
Cattle (head)	4,050	987	1,910	702
Pig (head)	3,228	2,581	3,864	3,081
Chicken (head)	20,387	19,543	25,222	22,629
Duck (head)	28,567	19,899	27,674	20,724
Main economic activities	Intensive Rice	Sugarcane	Sugarcane	Rice, aquaculture

(Sources: TCSO, 2012)

Chapter 5: SALINITY INTRUSION TREND AND ITS EFECTS ON AGRICULTURE IN THE MEKONG DELTA

5.1 Introduction

In this chapter the trend of salinity intrusion in the Mekong delta will be analyzed in connection with related factors (i.e. river flows, rainfalls, temperature) and based on the salinity concentration data from 4 gauging stations along Co Chien river (Tra Vinh and Hung My) and Hau river (Cau Quan and Tra Kha) between 1995 and 2010 (Figure 5.1). These rivers are among the nine main branches of the Mekong river delta discharging into the sea. Besides, it also explores the impacts of saline water intrusion on agriculture in the Mekong delta with special focus on Tra Vinh province based on secondary data and available literatures (the reasons for choosing Tra Vinh read detail in Chapter 3 – methodology).

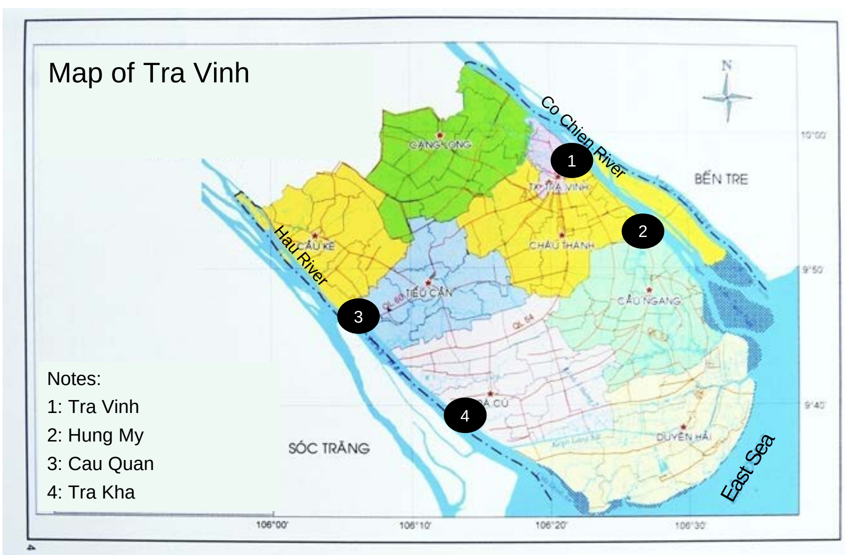


Figure 5.1: Map of Tra Vinh showing 4 salinity concentration monitoring stations

5.2 Salinity intrusion trend between 1995 and 2010

5.2.1 Mean of maximum salinity concentration by months

Monthly mean of maximum salinity concentrations in the dry season during the 16 years of the period 1995 – 2010 at representative gauging stations, two on the Co Chien river (Hung My and Tra Vinh stations) and two on the Hau river (Tra Kha and Cau Quan stations) are shown in Figure 5.2. It shows that salinity levels increase progressively from

January, reach peaks in March or April and decrease afterwards. Averages of 16 years, the highest levels of salinity concentration are 7.9, 14.2 and 18.0 g/l in March at Cau Quan, Hung My and Tra Kha stations respectively; whereas this figure is 9.0 g/l in April at Tra Vinh station (Figure 5.2).

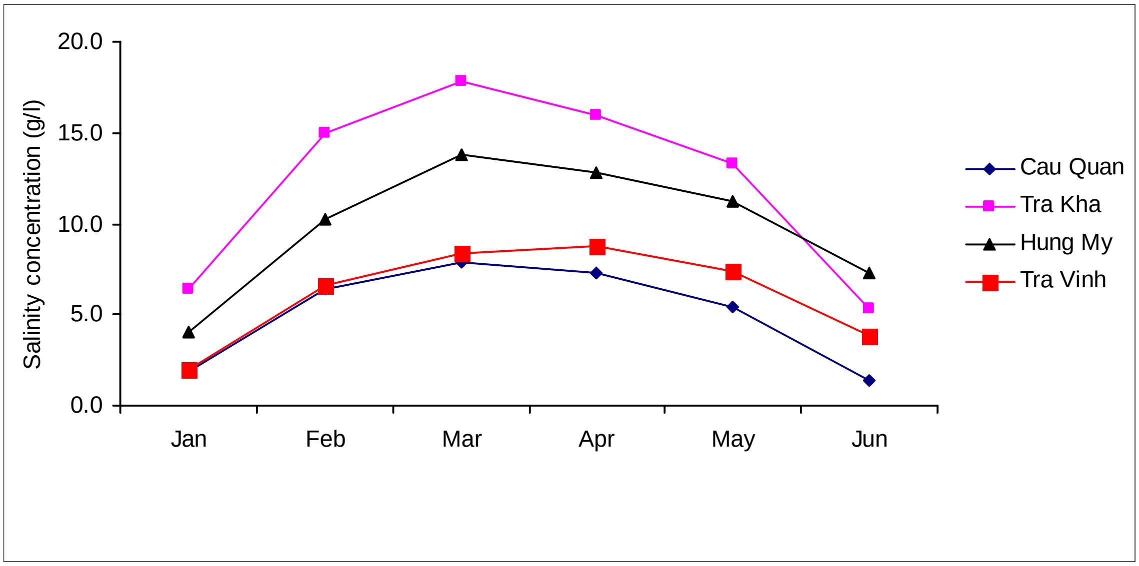


Figure 5.2: Monthly mean of maximum salinity concentrations at 4 stations in the period 1995 – 2010
(Based on data from the Center of Hydrometeorology in Tra Vinh)

Water circulation in the coastal zones of Mekong delta depends on many factors like geographical, climatic and anthropogenic conditions; in particular fresh water discharge of the rivers, local rainfall, tidal movement from the sea, the wind velocity/direction and water use regimes are important (Sam, 2006: p17; Tuan et al., 2007: p40). There is a closed relationship between salinity intrusion and freshwater discharge in the river branches in the delta. Figure 5.3 illustrates that river discharges at Tan Chau (upper Co Chien river) and Chau Doc gauging stations (upper Hau river) are very low in the dry season, especially in March and April. Average discharges in these two months are accounted for only 3 – 4% of the annual discharge (Figure 5.3). Therefore, there is not enough fresh water flow to prevent saline water to penetrate the river branches. It is considered as a major reason for salinity intrusion in river systems and canal networks in the dry season. Sam (2006: p197) calculated that on average the salinity concentration of 1 g/l can intrude 58 km further inland on Co Chien river and 54 km on Hau river in March.

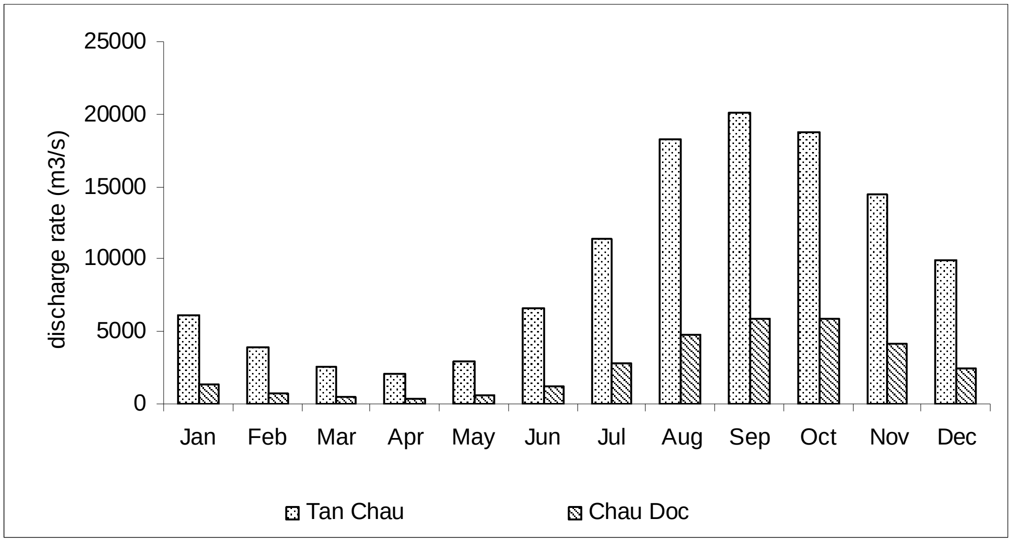


Figure 5.3: Monthly mean discharge rates (1995 – 2010) at Tan Chau and Chau Doc stations

(Based on data from the Southern Regional Hydro-meteorological Center)

Besides, weather data in Tra Vinh province shows that less than 20% of total precipitation falls in the dry season (November to April), especially from January to March there seems to be no rain; at the same time, temperature is rising up and getting its peak in April (Figure 5.4). High temperature causes higher evaporation. It is reported that evaporation rate in the dry season is bigger than in the wet season by about 2 mm per day in the coastal regions of Mekong delta (Sam, 2006). Hence, a combination of high evaporation rate and low rainfall in the dry season are important factors contributing to increase salinity related problems.

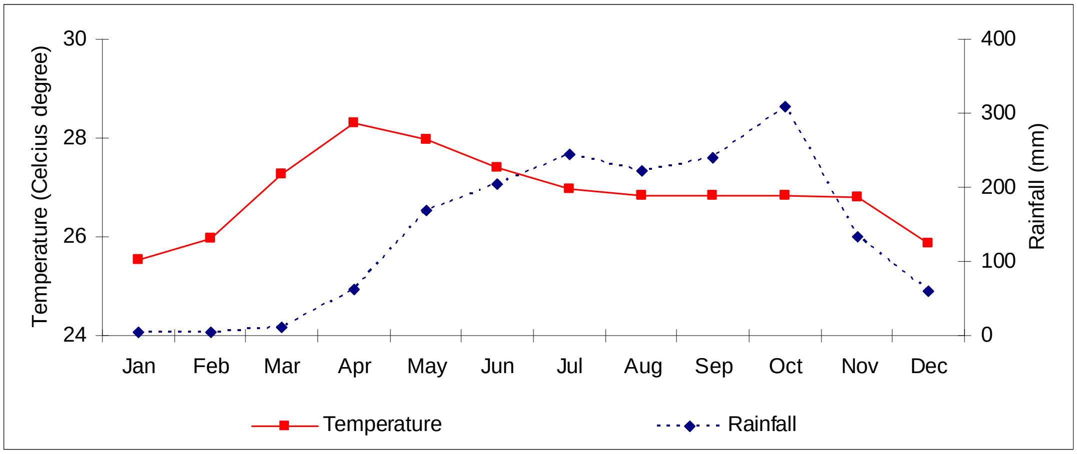


Figure 5.4: Monthly mean of temperature and rainfall (1995 – 2010) in Tra Vinh province

(Based on data from TVSO, 2000; 2003; 2006; 2011)

Salinity intrusion in the coastal regions is affected by tidal movement from the sea too. The Co Chien and Hau estuaries are influenced strongly by the semi-diurnal tides of the East Sea with large tide amplitude of 3.0 – 3.5 m (Tuan et al., 2007). Moreover, between January and April there are strong winds from the East Sea causing even higher (sea) water level in the river mouths, seriously affecting salinity intrusion in this period (Sam, 2006: p81-82).

Water use regimes also impact salinity intrusion, especially irrigation for Winter-Spring (WS) rice crop from November to April due to the fact that WS crop always needs more water than others (Figure 5.5). Total water requirement for 1 ha of rice in WS crop is about 8,080 m^3, of which 98% from irrigation systems. According to General Statistics Office, the WS crop area has been expanding from 1.0 to 1.6 million ha between 1995 and 2010 (GSO, 2000; GSO, 2011a). Most of this increase comes from upstream and mid-stream areas thanks to well-developed irrigation systems (Nhan et al., 2007: p152). Under this condition, fresh water scarcity clearly becomes more and more problematic issue in downstream regions in the dry season.

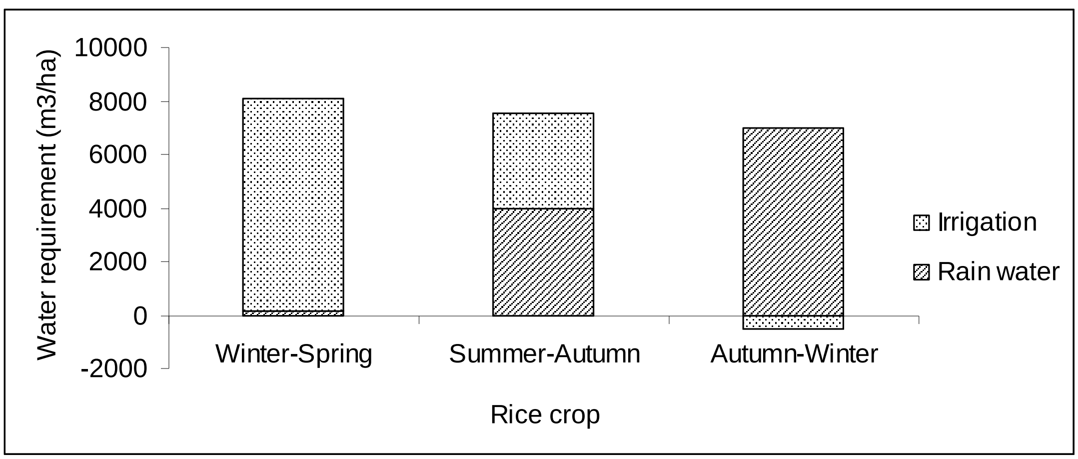


Figure 5.5: Total water requirement in different rice cropping seasons in the Mekong delta

(Based on data from Nhan et al., 2007: p153)

So far, it shows that on average salinity concentration in the Mekong delta reaches the highest levels in March or April every year. The state of sea water intrusion in this region is very complicated and affected by many factors among them not only natural conditions but also social development. Under recent socio-ecological changes how does salinity level vary? This issue will be analyzed in the following section.

5.2.2 Salinity intrusion trend in the period of 1995 – 2010

The annual mean of maximum salinity concentrations at 2 representative gauging stations, Hung My on Co Chien river and Tra Kha on Hau river are presented as Figure 5.6. The 16 years d long series (1995-2010) data show that:

At Hung My station: The lowest values of maximum salinity concentrations were observed in 1997 (7.4 g/l) or in 2000 (8.0 g/l). High values were observed in 2004 (21.6 g/l) or in 1998 (20.3 g/l). Between 1995 and 2010, the maximum salinity levels caused negative impacts in descending order as 2004, 1998, 2005, 2010, 2009, 1999, 2006, 2008, 2003, 1995, 2007, 1996, 2002, 2001, 2000 and 1997.

At Tra Kha station: The lowest values of maximum salinity concentrations were also observed in 1997 (12.5 g/l) or in 2000 (14.1 g/l). High values were observed in 2005 (22.8 g/l) or in 1998 (22.1 g/l). Between 1995 and 2010, the maximum salinity levels caused negative impacts in descending order as 2005, 1998, 2010, 2006, 2004, 2008, 1995, 2007, 1996, 1999, 2001, 2002, 2003, 2009, 2000, and 1997.

Average of 4 stations (Hung My, Tra Kha, Cau Quan and Tra Vinh), the maximum salinity levels caused negative impacts in descending order as 1998, 2004, 2005, 2010, 2008, 2006, 1999, 1995, 1996, 2007, 2009, 2003, 2002, 2001, 2000, and 1997.

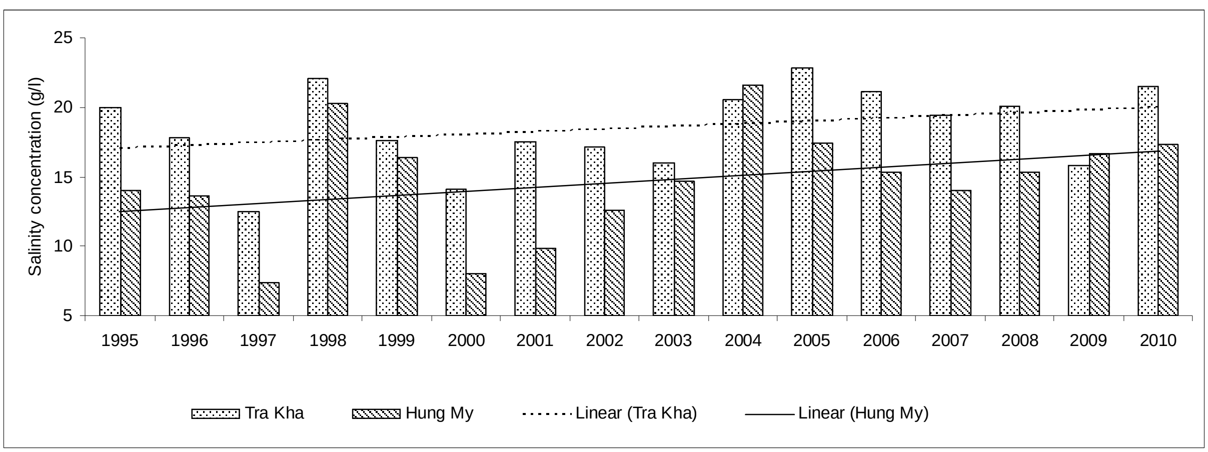


Figure 5.6: Salinity intrusion trends between 1995 and 2010 at Hung My and Tra Kha stations

(Based on data from the COH-TV)

Salinity intrusion in the Mekong river systems alters year by year resulting from many factors, of which upstream discharge flow is perceived as an important one. A simple regression model like Figure 5.7 demonstrates that salinity level in downstream has inverse relationship with upstream discharge. It means that less fresh water discharge of the Mekong from upstream causes more salinity intrusion in downstream areas and vice versa.

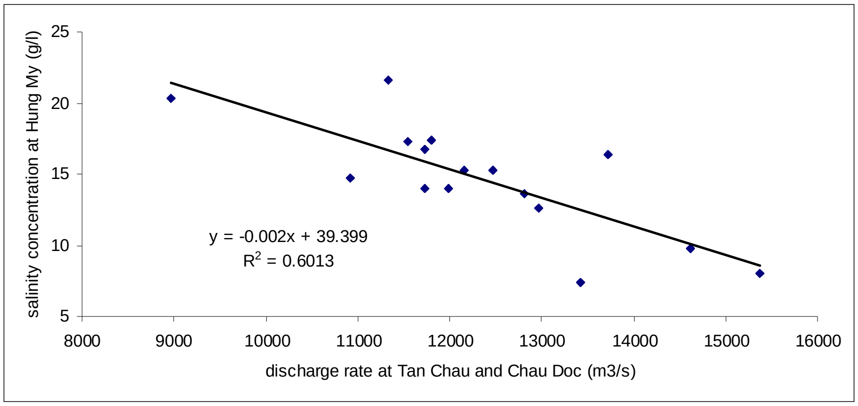


Figure 5.7: Relationship between salinity concentration in downstream and discharge rate from upstream in the period of 1995 – 2010

(Based on data from the COH-TV and SRHMC)

As mentioned, in 1997 and 2000 the salinity concentration received the lowest values at all stations over the period of 1995 – 2010. This has a close relationship with river discharge from upstream. The 2000 flood is considered as "historical flood" in the Mekong delta because of high discharge peak (Tuan et al., 2007). The hydrological data show that monthly mean of discharge rate in 2000 at Tan Chau and Chau Doc was very high compared to the averages; for example, 15.367 m^3/s in comparison with 12.322 m^3/s (Data from the Southern Regional Hydro-meteorological Center). Physically, a large fresh water discharge from upstream prevented saline water penetration in the coastal regions then salinity level was low in 2000. However, flood in 1997 was not a big one but this is a special year because the discharge rate at Tan Chau and Chau Doc from January to April was bigger than the averages (Table 5.1) that why salinity intrusion was less in the dry season of 1997.

Table 5.1: Comparison of monthly mean discharge flow (m^3/s) in 1997 and the average of 1993 – 2007 at Tan Chau and Chau Doc stations

Time	Tan Chau				Chau Doc			
	Jan	Feb	Mar	Apr	Jan	Feb	Mar	Apr
Year of 1997	8,140	5,330	3,230	2,620	2,020	1,160	661	547
Averages of 1993-2007	6,112	3,930	2,529	2,058	1,331	752	485	400

(Data from Southern Regional Hydro-meteorological Center)

The highest value of salinity concentration over the period of 1995 – 2010 happened in the year of 1998 that is also explained under river flow regime. As mentioned, average (1995 – 2010) of monthly discharge rate at Tan Chau and Chau Doc was about 12,322 m^3/s but this figure was only 8,966 m^3/s in 1998. Besides, the rainfall was less by end of 1997 and beginning of 1998 than normal years (Table 5.2). A combination of low discharge flow from upstream and less local rainfall caused serious salinity related problems in the lower Mekong delta in 1998.

Table 5.2: Comparison of monthly rainfall (mm) in the dry season of 1997 – 1998 and the average of 1995 – 2010 at Tra Vinh station

	Dec	Jan	Feb	Mar	Apr
The dry season of 1997 – 1998	3.4	0.0	0.0	0.0	13.5
Averages of 1995 – 2010	59.0	5.3	3.8	10.9	63.1

(TVSO, 2000, 2003, 2006, 2010, 2011)

Although the salinity concentration fluctuates irregularly year by year due to many drivers but its trend seems to be increasing as illustrated by trend-lines in Figure 5.6. It is clearer when the 16 year data series (1995 – 2010) is divided into 2 time-spans for comparison such as the previous time-span from 1995 to 2002 and the latter time-span between 2003 and 2010 like shown in Table 5.3.

Table 5.3: Comparison of monthly maximum salinity concentration (g/l) between two time-spans at Hung My and Tra Kha stations

Stations	Time-spans	February	March	April	May
Hung My (Co Chien river)	Period 1 (1995 – 2002)	8.9	11.7	11.0	9.2
	Period 2 (2003 – 2010)	11.9	16.2	14.8	13.6
	P-value (t-test)	*0.121*	*0.035*	*0.014*	*0.001*
Tra Kha (Hau river)	Period 1 (1995 – 2002)	14.1	16.7	15.1	12.7
	Period 2 (2003 – 2010)	15.9	19.1	17.0	13.9
	P-value (t-test)	*0.225*	*0.113*	*0.123*	*0.379*

(Based on data from the Center of Hydrometeorology in Tra Vinh)

Table 5.3 shows that the mean values of maximum salinity concentrations in Period 1 are lower than in Period 2 in all dry months at both Hung My and Tra Kha stations. That means not only bigger salinity concentrations but also longer duration of saline water in recent years. For example, taking average of monthly maximum salinity concentration at

Hung My station in two different time-spans, it shows that the mean values increased from 8.9 g/l in February to 11.7 g/l in March and decrease afterward as 9.2 g/l in May for Period 1 whereas this value was still high as 13.6 g/l in May for Period 2. This trend is the same for other stations and corresponds with previous studies in other coastal provinces of the Mekong delta (Sam, 2006; My and Vuong, 2006; Kotera et al., 2008; Tran and Likitdecharote, 2010). Therefore, it is clear that salinity intrusion has been increasing. It starts earlier and ends later and is causing a lot of difficulties, especially for agricultural practices like rice farming. Effects of salinity related problems to agriculture in the Mekong delta are described in the following section.

5.3 Effects of salinity intrusion on agriculture

5.3.1 Land area affected by saline intrusion

Salinity affected land areas by different saline intrusion regimes are presented in Figure 5.8. On average, around 2.13 million ha of land (54.5% of total delta) are affected by saline water in April every year. As discussed, over the period of 1995 – 2010 salinity intrusion was serious in 1998 and that impacted on 2.43 million ha of land (62.4% of total delta). In 2000, the salinity concentration was at the smallest level during the 16 year data series but it still caused 1.88 million ha of land (48.3% of total delta) to be affected by saline water intrusion, of which 77.0% by saline water above 4g/l.

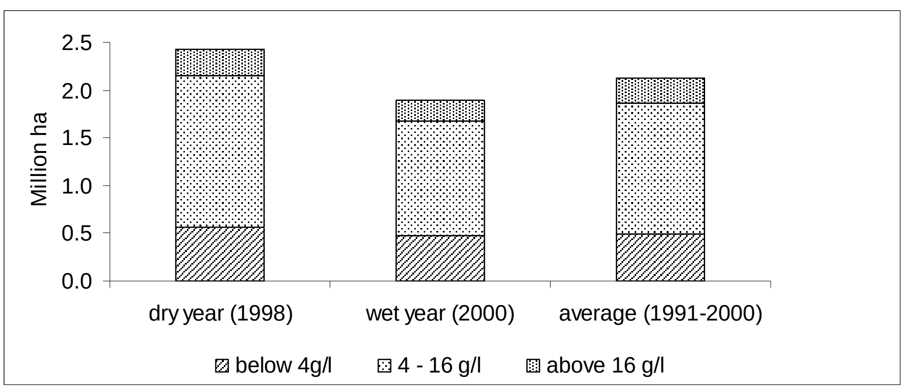


Figure 5.8: Salinity affected areas in different hydrological years in April in the Mekong delta
(Based on data from Sam, 2006)

Nhan et al. (2012) reported that up to 4g/l of salinity level, farmers can maintain their rice production and income with good rice varieties tolerant to salinity and proper agro-chemicals applications but if salinity level climbs above 4 g/l they need to shift to other farming systems instead of intensive rice cultivation. Hence, salinity intrusion is perceived as a major constraint for agricultural development in the Mekong delta. However, many sluice gates and dyke systems have been built to prevent saline water from entering rice farming areas in the Mekong delta (see Chapter 4, section 4.2.4).

5.3.2 Rice area affected by saline intrusion

Among other crops rice is dominant as accounted for above 90% of total planted annual crops in the Mekong delta (GSO, 2013) but it often faces with salinity related problems, especially in the coastal provinces. Asch and Wopereis (2000) documented that rice yield is reduced by 0.4 – 0.6 ton per ha for every unit (1g/l) increase in water salinity for salinity levels above 1.3 g/l. In the Mekong delta, Nhan et al. (2012) also found the rice yields can be down by 0.2 – 1.4 ton per ha for 1g/l increase in term of salinity concentration depending on rice varieties. Annually, out of 650,000 ha of rice grown in the lower delta about 100,000 ha is being at risk to salinity intrusion, seriously in the case of a drought in the early or late periods of the rainy season (MARD, 2011: p143).

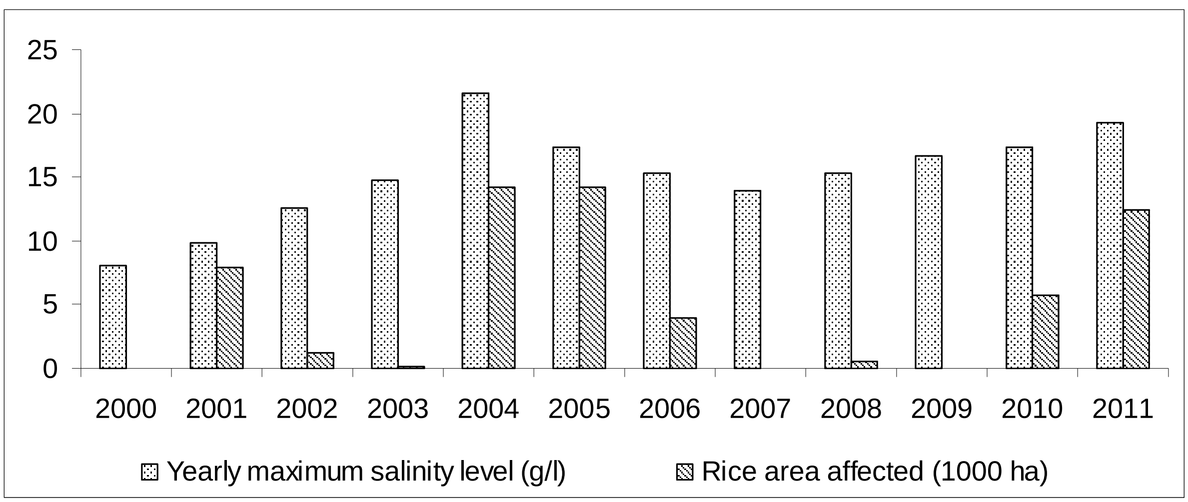


Figure 5.9: Rice area affected in Tra Vinh province and maximum salinity level at Hung My station

(Based on data collected from DARD-TV and COH-TV in 2011)

Detailed analysis of data collected from Tra Vinh province shows that on average there was about 5,000 ha of rice damaged by salinity related issues every year over the period of 2000 – 2011 (Figure 5.9). Normally, more rice areas should have been affected in the dry years like 2004 and 2005 when salinity levels were high. However it is not always true. Figure 5.9 illustrates that the salinity concentrations during 3 years from 2009 to

2011 were more or less the same as in 2005 but less areas was affected than in 2005. This can be explained by other reasons then the natural factors causing high salinity concentration in rivers and canals. According to key informant interviews taken in 2011, there were 3 main reasons. Firstly, the sea water control structures such as dykes, sluice gates and canals have been improving recent years. Secondly, the Department of Agriculture and Rural Development in collaboration with the Irrigation Company provide better seasonal calendar for seeding and watering. Thirdly, proper technologies and innovations are applied through agricultural extension development. However, people can question why serious damages happened in 2011 when affected areas reached around 12,000 ha. To answer the question, it is necessary to analyze the 2011 situation in particular.

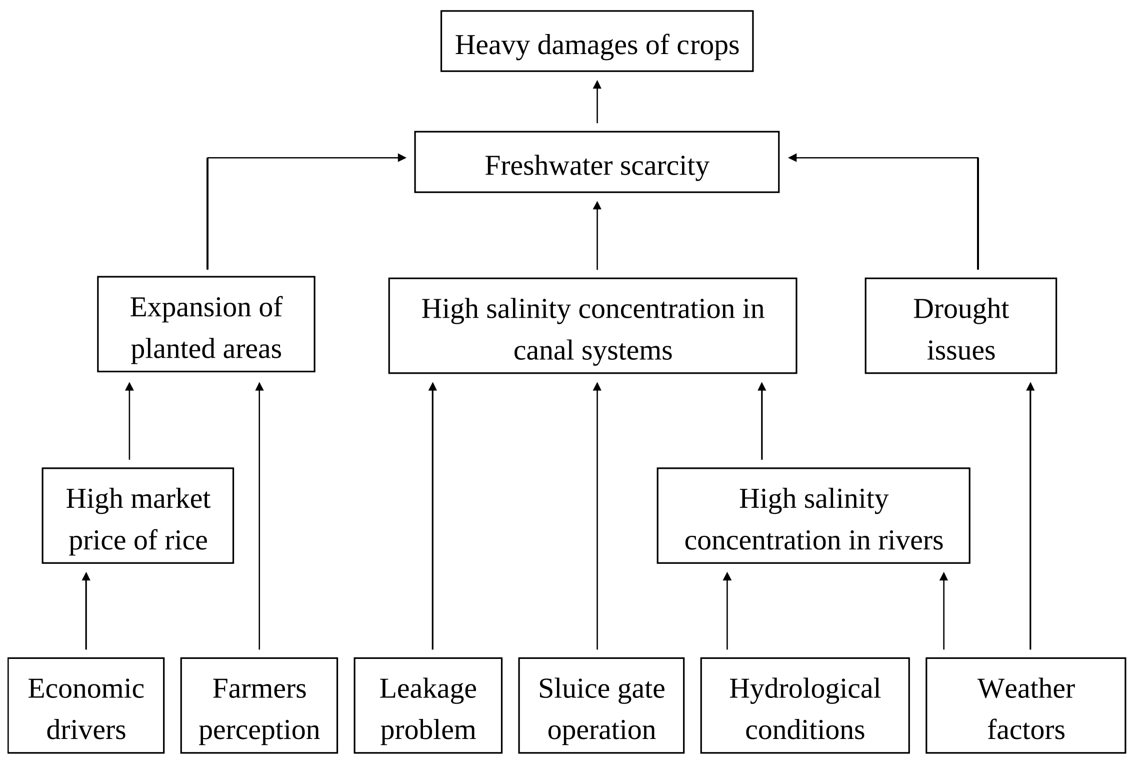


Figure 5.10: Causal diagram of serious damages of affected rice areas by salinity related problems in the 2011 dry season in Tra Vinh province

(Drawn from KI interviews, 2011)

In 2011, in Tra Vinh the serious salinity related problems on rice were caused by multiple-causes. Out of 59,516 ha of rice grown in the 2011 WS crop, about 11,827 ha (or 20% of total areas) of 16,401 households were affected by salinity related problems; of which the damage levels from 30 – 70% affected 2,148 ha and above 70% 9,679 ha (TVSO, 2012; PPC-TV, 2011). Like illustrated in Figure 5.10, besides dry weather and negative hydrological conditions causing high salinity concentration in rivers (see section 5.2 for more explanation) there are other reasons that led to heavy damages on rice crop in 2011 such as economic drivers, farmers perception, leakage problem and sluice gate operation issues.

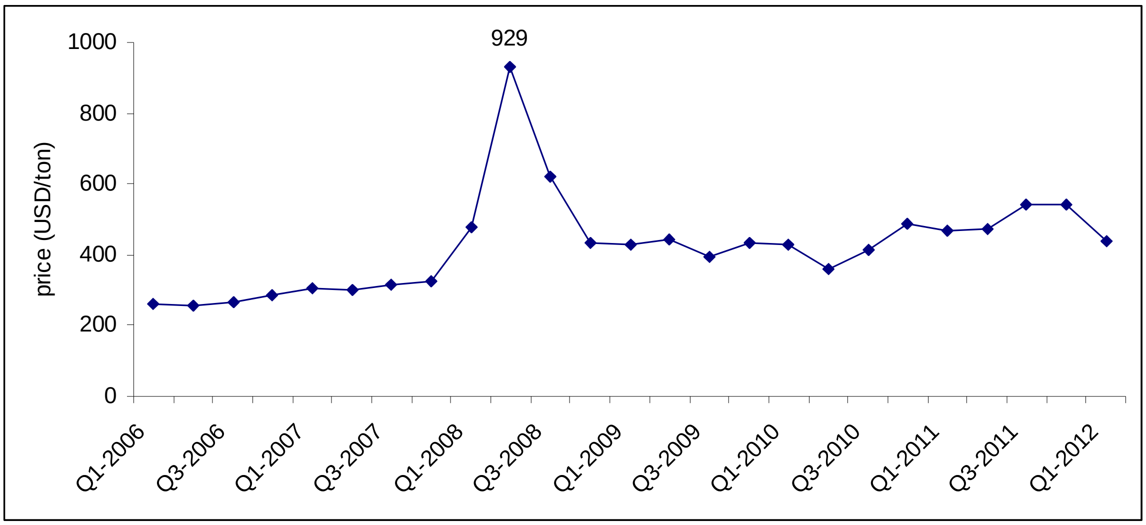


Figure 5.11: Average of Vietnamese milled rice export price (ton/ha) by quarters between 2006 and 2012

(Based on data from USDA, 2012 and VFA)

The world market rice price has been increasing since 2006 and faced a food price crisis in 2008 (Childs and Kiawu, 2009: p2). Figure 5.11 shows before 2008 the rice export price in Vietnam was around 300 USD per ton but it had a big jump in 2008 and reached a peak in mid-2008 at 929 USD and fluctuated above 400 USD afterwards. Under high market price, planted rice areas have been grown up even in freshwater difficult regions like coastal districts. In these regions farmers have introduced new crop (WS) in the dry season and expanded year by year because it was successful in some first crops. Statistical data proved recent years the WS crop in Tra Vinh increased gradually around 3,000 ha per year from 49,698 ha in 2008 to 59,517 ha in 2011, most of this expansion from coastal districts like Tra Cu, Cau Ngang and Chau Thanh (Figure 5.12). This figure also illustrates that large damaged areas by salinity related problems in the 2011 WS crop fall in the "new" planted regions; for example, in Cau Ngang 93% of planted areas was affected while in upper districts as Cang Long and Cau Ke no affected areas were found. From the heavy loss in 2011, farmers have perceived that these expansion regions were highly risky to dry season salinity; then in many cases they stop seeding in the 2012 dry season (KI interviews, 2012). Therefore, one can conclude the increase of planted areas in the WS crop results from the high market price and farmers' perception.

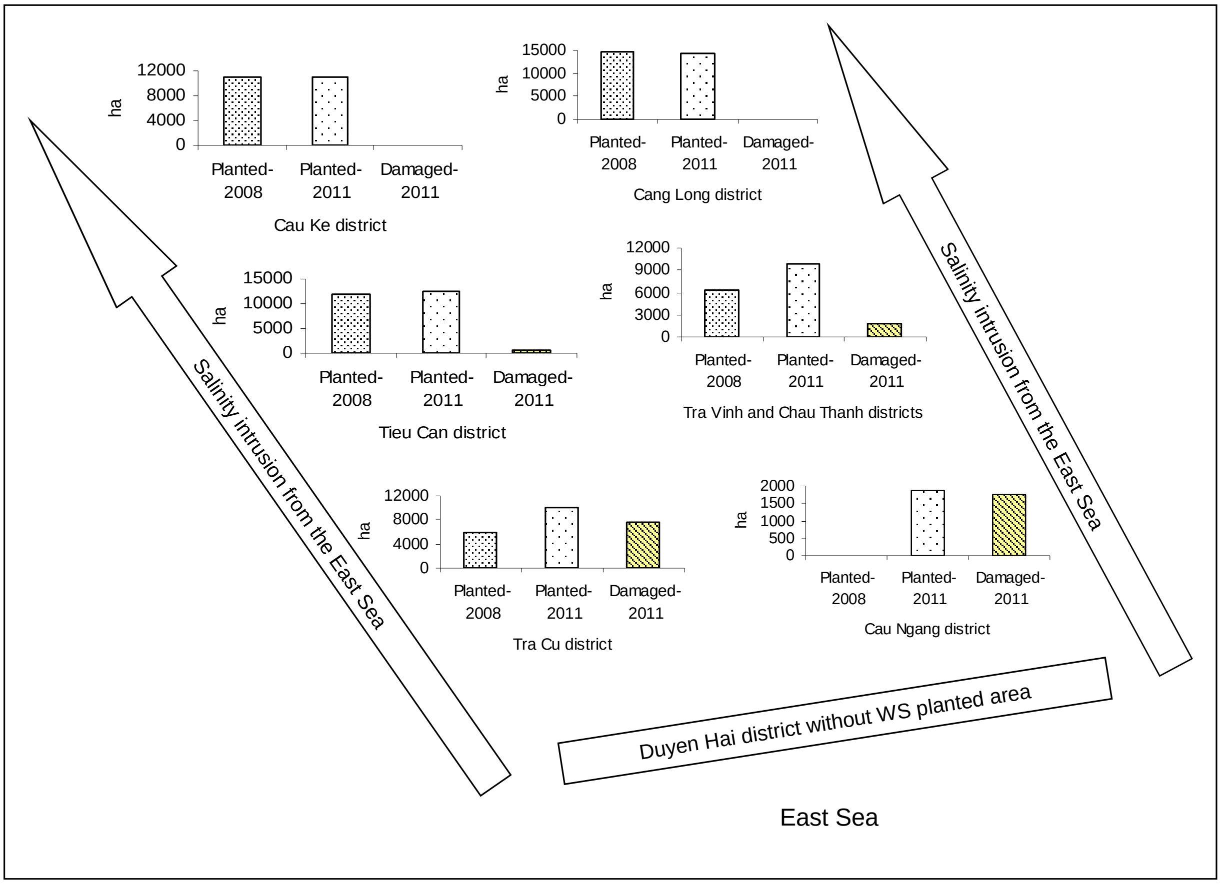


Figure 5.12: Planted and damaged areas in winter-spring rice crops by different district location in Tra Vinh province

(Based on secondary data collected in 2011)

Leakage problem and sluice gate operation issues also contribute to increase salinity level in canal systems. It is noted that the 2011 salinity season came earlier than in "normal" years. For example, at Hung My station the average (1995-2010) of maximum salinity in January was about 4.0 g/l where as it was recorded at 7.6 g/l in January 2011 (Data collected from COH-TV, 2011). Moreover, the salinity concentration increased very fast in short time at the beginning of the 2011 dry season and the sluice gates could not close immediately due to their technical designs (KI-interviews, 2011). A combination of high salinity level in rivers, leakage through dykes and improper sluice gate operation caused high salinity concentration in canal networks. At many inland locations the salinity levels were above 4 g/l (Table 5.4) whereas common crops can not grow with such high salinity concentration; for example, salinity level in water excess of 1 g/l can affect rice yields (Grattan et al., 2002: p189). Then farmers could not water for the plants in the meantime.

Table 5.4: Maximum salinity levels in 2011 at selected sites in Tra Vinh province

Name of stations	Location	Maximum salinity levels (g/l)	
		From field side	From river side
Vinh Kim sluice gate	Cau Ngang district, from Co Chien river side	14.7	14.7
Nha Tho sluice gate	Chau Thanh district, from Co Chien river side	4.8	10.3
Can Chong sluice gate	Tieu Can district, from Hau river side	8.3	11.6
Ngoc Bien bridge	Tra Cu district, from Hau river side	4.1	---

(Source: Data collected from Department of Irrigation in Tra Vinh)

In short, the rice was damaged seriously in the 2011 WS crop in Tra Vinh province because of freshwater scarcity that results from expansion of planted areas in coastal districts, high salinity concentration in canal systems and dry weather factors. Kotera et al. (2008: p271) also concluded the rice yield of WS crop decreases in districts with higher salinity concentration when they analyzed the relationship between rice production and salinity at 30 districts in the Mekong coastal regions. It is noted that not only rice but also other crops like sugar-cane, fruit trees, beans and vegetables were affected by salinity related problems, however there are not enough data for detailed analysis of such crops.

5.4 Conclusion

In normal year salinity level in the Mekong river system starts to rise from December, reaches its peak in March or April and declines afterwards, but recently the salinity intrusion trend has increased in terms of concentration and duration. Sea water tends to come earlier, intrudes further inlands and remains longer in the dry season. This is a complicated phenomenon and not easy to forecast accurately. It can change year by year even daily due to a bundle of related factors including weather and hydrological conditions. Most of them are uncertainty like rainfall, temperature, wind, tidal movement and sea level rise. Besides, socio-economic developments from upstream countries as well as upper provinces in the Mekong delta result in river flow alteration that causes more vulnerability in the coastal communities. In general, a probability of dry year increases but its prediction (which year and how its process) is still a challenge. Hence, there are need for weather forecast improvement and better coordination and collaboration among water users in the whole river basin.

Agricultural production in the lower delta has obtained some protection mainly thanks to hydraulic structural investments (i.e. sluice gates and dykes) to prevent sea water intrusion but crops always face the high risk to salinity intrusion because of abnormal weather (i.e. shorter rainy period, earlier salinity intrusion), leakage problem and inappropriate sluice gate operation. Besides, high market prices of agricultural production attract farmers to expand planted areas even in high risk regions that increase threats to salinity related problems. Therefore, it is necessary to take into account not only natural but also social drivers for disaster risk reduction and sustainable agricultural development in the Mekong delta.

Shortly, salinity intrusion is a slow-onset hazard and difficult to predict then the damages are often huge in case of abnormal years. Under the contexts of social, economic and environmental changes at regional as well as global levels, the salinity related problems will increase. Hence, it is important to pay more attention to this new increasing hazard and rethink adaptation measures including both structural and non-structural options instead of focusing on dyke constructions for rice production purpose alone. Next chapter will discuss current vulnerability, coping and adaptation to salinity intrusion in different socio-ecological settings at community level and draw lessons learnt for better adaptation strategies.

Chapter 6: PARTICIPATORY VULNERABILITY ANALYSIS – A CASE STUDY FROM SALINITY INTRUSION IN THE LOWER MEKONG DELTA

6.1 Introduction

As shown in the previous chapters salinity intrusion has been increasing in the Mekong delta and affecting agricultural production as well as livelihoods of the coastal communities in the last decades. To cope with and to adapt to this hazard, both formal (by authorities) and informal (by individuals) adaptation options have been developed and implemented. They have shown many positive results for agricultural and economic developments as farmers can grow two or even three rice crops per year. However, there are still many issues that need to be addressed. This chapter presents findings of vulnerability assessment and to draw some lessons learned from past adaptation strategies to salinity intrusion in the lower Mekong delta. The results were mainly obtained from the expert interviews and participatory vulnerability analysis (PVA) at different levels from province to district, village and community as well as observations from the field visits in Tra Vinh province between 2009 and 2011. In some parts, the qualitative results from a household survey (HHS) are provided to supplement the PVA findings (see Chapter 3 for detail of methodology). The chapter is structured into three main parts corresponding to three vulnerability components as hazard exposure, susceptibility, coping and adaptation in different social-ecological settings in the study site of Tra Cu district, Tra Vinh province.

6.2 Hazard profiles in three social-ecological zones

Tra Cu district is located in the coastal province of Tra Vinh. Historically, it had been affected by salinity related problems but it has been reduced in the last three decades through hydraulic work development as indicated in Table 6.1. Before 1975 the district was strongly impacted by sea water intrusion which caused freshwater scarcity in the dry season (November to May) due to low discharge from Hau River (one of the Mekong River branches), less local rainfall and tidal influence from the East Sea (see Section 5.2 in Chapter 5 for status of the hazard). Therefore, farmers could grow only one traditional rice crop based on rain water with very low yield (about 2 tons per ha) in the rainy season. During salinity periods, the fields were covered by saline water with abundant in natural fish and shrimp that contributed large incomes for people here. After the reunification of the country (1975), La Bang dam and Ba Thang Hai canal were constructed by local human resources in order to prevent sea water intrusion that allowed farmers intensify their farming as double rice cropping areas increased from 600 ha in 1980 to around 5,000 ha in 1985. Step-by-step the hydraulic structures have been improved and the freshwater regions have been expanded as double cropping areas rose up to 10,000 ha by 1995. In addition, since 1995 series of embankments and sluice gates were built in many locations of the district to control sea water under a framework of the South Mang Thit Sub-project (SMTS) from the World Bank fund. Thanks to irrigation development, agriculture has been intensified and diversified. Currently about 17,000 ha are suitable for two crops and 7,000 ha for three crops per year in the district. High yielding varieties (HYV) have been strongly applied since 1990s that contributed to increase yields and productions. For example, average of rice yields over the period of 1995 – 2010 rose from 3.5 to 4.5 tons per ha per crop while the production from 79,500 tons to 195,000 tons in the same period (Table 6.1).

Table 6.1 Hydraulic structure development and its impacts on rice farming in Tra Cu district

Time	Events	Impacts
Before 1975	War period, weak irrigation systems	Strongly affected by salinity intrusion Only 1 traditional rice crop in the rainy season (June to late November) with the yield about 2 tons per ha Harvested natural fish and shrimp during saline water intrusion (December to May)
1976-78	Dug Ba Thang Hai canal (primary level) Constructed La Bang dam (the key dam in Tra Cu)	Reduction of salinity affected areas Starting to cultivate the second crop (double rice cropping pattern) with high yielding varieties
1980-95	Development of the irrigation systems (secondary and third canal levels)	Freshwater was available for bigger areas Double rice cropping areas increased from around 600 ha in 1980 to 5,000 ha in 1985 and 10,000 ha in 1995 Rice yields raised from 2,0 to 3,5 tons per ha per crop (1980-1995)
1995-current	Implementation of the South Mang Thit Sub-project (SMTS)	Sea water has been prevented from intruding inside the SMTS areas Agriculture is intensified and diversified Double rice cropping areas are about 17,000 ha, triple cropping areas are 7,000 ha Rice yields raised from 3.5 to 4.5 tons per ha per crop while the production from 79,500 tons to 195,000 tons in the 1995-2010 period Besides, upland crops, fruit trees and animals are also introduced

(Drawn from expert interview)

Although the SMTS have brought a lot of benefits for agricultural development, however the district remains highly vulnerable to salinity risks. Figure 6.1 illustrates that the maximum salinity concentrations at some selected points were relatively high, even inside the SMTS where they are expected to be zero. Based on hydrological regimes, topological conditions, irrigation systems and agricultural production activities, Tra Cu is divided into 3 different zones (Figure 6.1). Each zone has particular activities and faces varying constraints which is summarized in Table 6.2 and analyzed in detail as following sections.

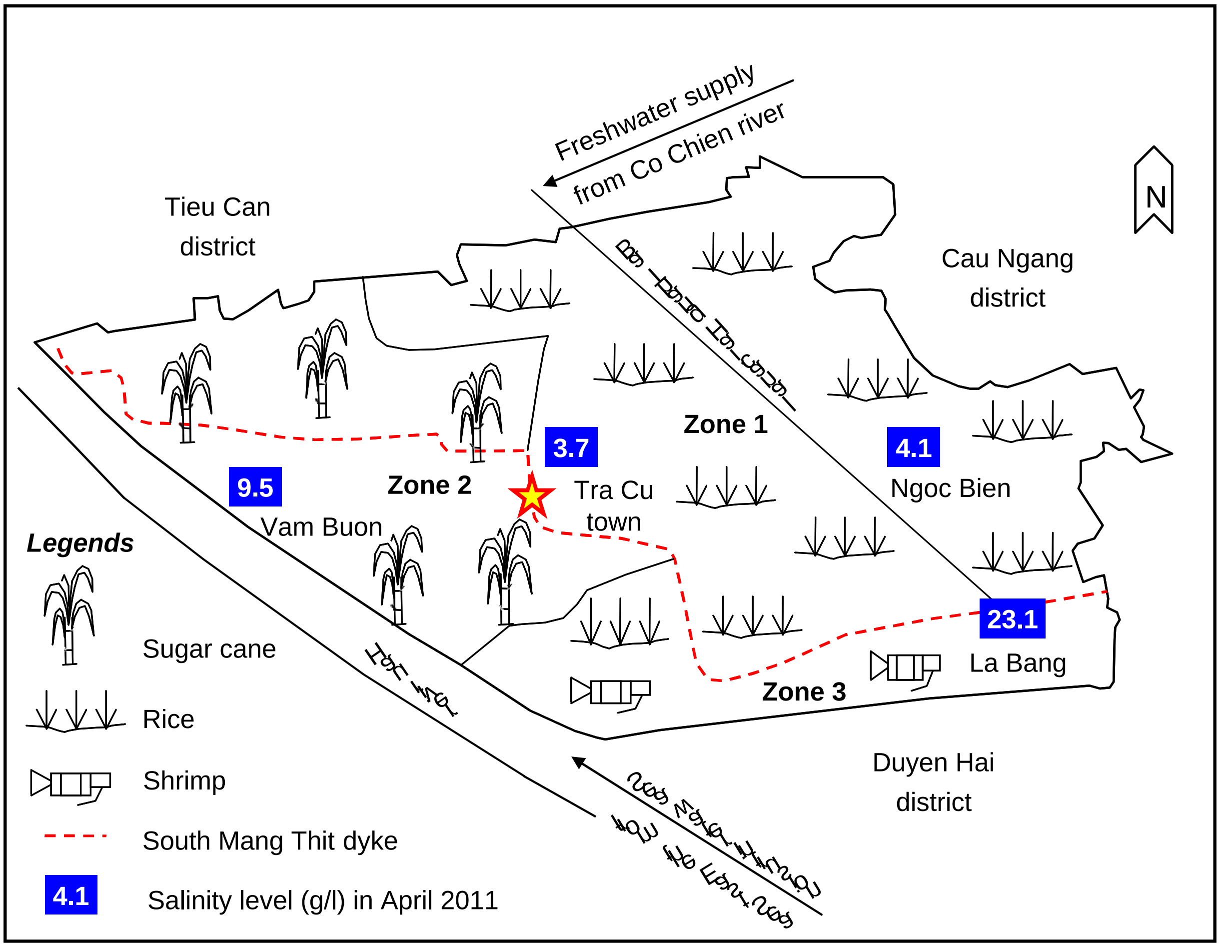


Figure 6.1: The map of Tra Cu showing three different zones and salinity levels in April 2011

(Mapping exercise with DARD staff in Tra Cu district, 2009; salinity level updated in 2011)

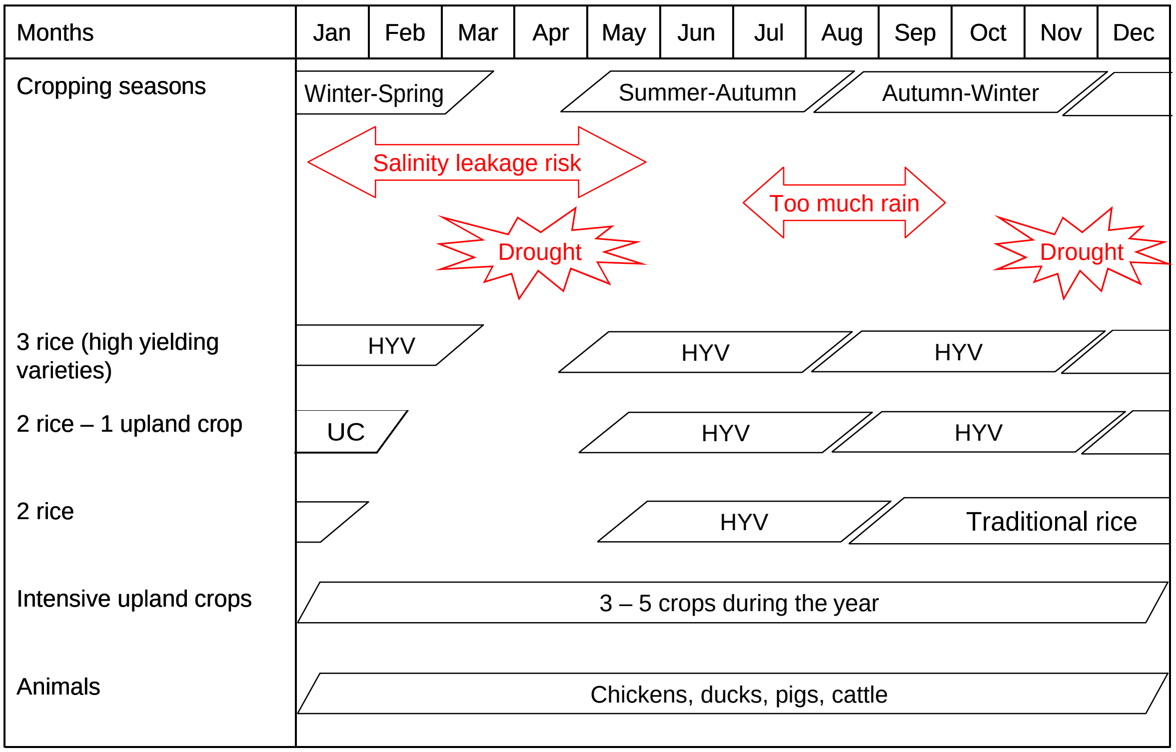
Table 6.2 Characteristics of three different zones in the study site

	Zone 1 (rice zone)	Zone 2 (sugarcane zone)	Zone 3 (aquaculture zone)
Area	25,300 ha (69% of total land)	8,000 ha (22% of total land)	3,500 ha (9% of total land)
Irrigation systems	Freshwater whole year Good irrigation system thanks to SMTS (100% inside SMTS)	1/3 freshwater whole year (inside SMTS) and 2/3 affected by sea water in the dry season (outside SMTS)	Sea water intrusion in the dry season (100% outside SMTS)
Main economic activities	2 to 3 rice crops per year 2 rice – 1 upland crop Upland crops (maize, peanuts, vegetable, etc) Cattle, pigs, poultry	Sugarcanes 1 to 2 rice crops per year Upland crops inside the SMTS (maize, peanut, vegetable, etc) Less animal husbandry	Aquaculture and fishing Rice-shrimp system (1 rice crop in the wet season and 1 shrimp crop in the dry season) Less animal husbandry
Major hazards and problems	Drought weather caused freshwater scarcity in the dry season (especially from February to May) Improper sluice gate operation, leakage problems Inundation in the wet season Whirlwind	Sea water intrusion can destroy or reduce crop production Freshwater scarcity (outside SMTS) Affected by tidal influence (flooding) Whirlwind Storm (seldom)	Shrimp diseases Brackish water can destroy or reduce crop production Freshwater scarcity Affected by tidal influence (flooding) Whirlwind Storm (seldom)

6.2.1 The rice zone

The rice zone (Zone 1) covers an area of 25,300 ha, accounted for about 69% of total district area. In this zone, sea water intrusion has been controlled owing to the SMTS which allowed the agricultural development as the area under double and triple cropping have been increased. Currently, there are 3 major rice-based farming systems in the freshwater area as shown in Figure 6.2. A dominant farming pattern here is triple rice cropping with HYV namely winter-spring (WS), summer-autumn (SA), and autumn-winter (AW) crops. Some areas where irrigation works are not functioning very well or the land elevation is relatively high, farmers cultivate 2 rice and 1 upland crop (i.e. maize, peanut, water melon) rotation or double rice cropping to deal with drought weather in the dry season. It is to be noted that with double cropping model the HYV is often replaced by traditional rice in the AW crop season because of higher profits obtained from traditional rice compared to the HYV. Intensive upland crops like vegetables, peanuts, beans, and cucurbits are also cultivated in irrigated regions during the year. Animals (i.e.

chicken, duck, pig, cattle) are raised at small scale during the year in this zone. In Zone 1 more development can take place than in the other two zones.



Note: HYV = high yielding varieties, UC = upland crops

Figure 6.2: Seasonal calendar of major farming patterns and hazards in Zone 1

The PVA results showed that major hazards in Zone 1 include drought weather causing freshwater scarcity in the dry season, salinity intrusion through sluice gate and dyke leakages as well as improper sluice gate operation, too much rain causing inundation in low land areas and whirlwind. Droughts often happen 2 times in the year from February to May and from November to December. The first drought period impacts young rice in SA crop while the second one effects the flowering period of AW crop and early stage of WS crop (Figure 6.2). They can become a serious threat in cases of low discharge from upstream, late or/and shorter rainy season. Although Zone 1 is situated inside of the SMTS where perceived as safe from salinity intrusion but it still faces with saline water penetration from January to April because of risks regarding to leakage problem and/or improper sluice gate operation. This not only impacts directly the WS crop but also delays the seeding time of SA crop. Theoretically salinity level inside the dyke systems should be about zero; however, in many locations in the freshwater zone salinity concentrations are above 1 g/l even during closed-gate time thus it becomes stressful to rice (Figure 6.1). A combination of drought weather and salinity intrusion at the same time always causes more stress for crops. If they happen in sensitive stages of rice growth (seeding, flowering) then the crops can be partly or totally damaged (Box 6.1). About 20% of the interviewed rice farmers reported they have been affected in the past by drought weather and salinity intrusion which caused not only a reduction (41%) of the crop yield but also in quality. Resulting from these are increased costs of production (4%) and decreasing prices (27%) for the produce (HHS, 2010). Besides salinity and drought problems in the dry season, too much water causing inundation in the wet season is also recorded, especially at the ending of SA and beginning of AW crops. It is more problematic for low lying land and for less than optimally irrigated regions. If rain is heavy then the harvests of SA crop are affected and the AW crop will be planted late. In cases of late cultivation whether in SA by salinity related issues or in AW by heavy rain, it will put the next WS at higher risk to salinity and drought hazards because of tardy cropping season (Figure 6.2). In conclusion, the Zone 1 belongs to freshwater area characterized by intensive rice farming systems; however, it has to deal with freshwater scarcity and salinity related problems that can sometimes develop to a threat for agricultural activities.

Box 6.1: Rice affected areas by salinity and drought problems in Tra Cu district

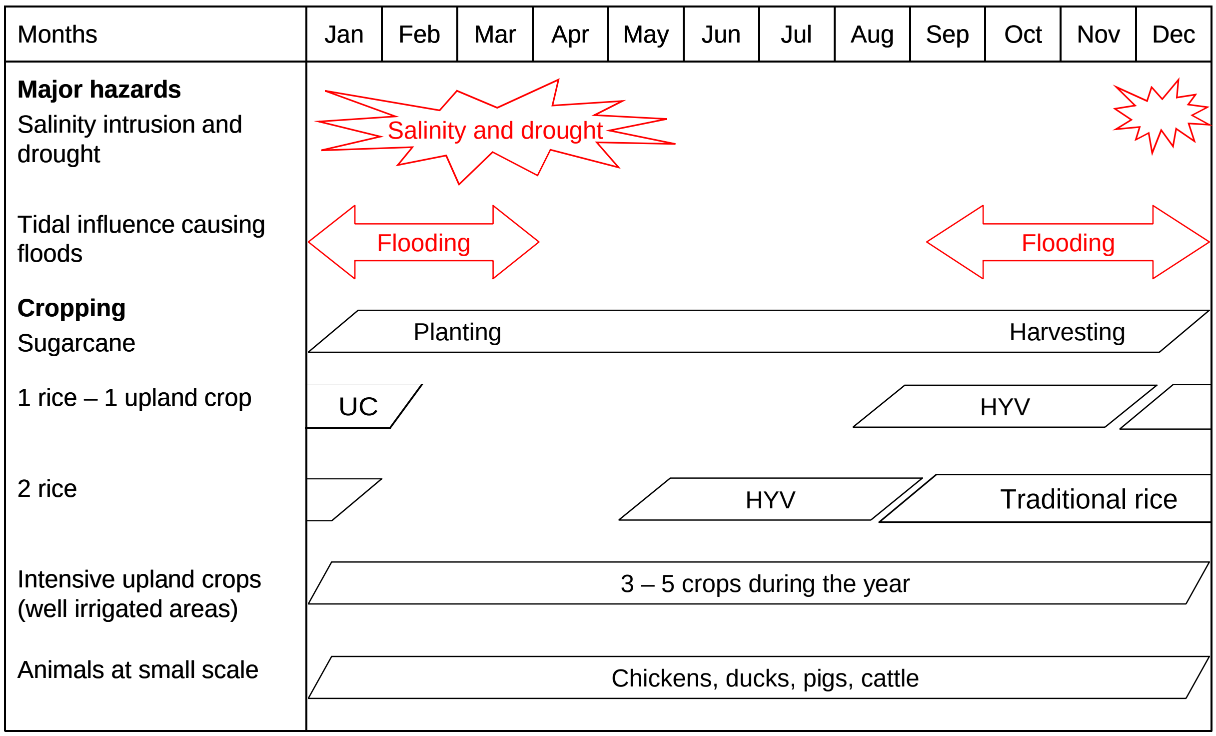
- *In 2009-2010 WS crop:* 970 ha (about 10% of total planted areas) were affected by freshwater scarcity due to dry weather and high salinity concentration in river and canal networks.
- *In 2010 SA crop:* drought impacted 1,236 ha (about 8% of total planted areas); of which 143 ha were damaged from 30 to 70% and 1,093 ha were damaged above 70%. Such damages affected 2,032 farmers.
- *In 2010-2011 WS crop:* 7,548 ha of 9,673 households were damaged as combined result of salinity intrusion and drought; of which 89% were totally damaged and the rests were affected from 30 to 70%.

(Sources: Data collected from Department of Agriculture and Rural Development in 2011)

6.2.2 The sugarcane zone

The sugarcane zone (Zone 2) occupies an area of 8,000 ha, of which about 1/3 belongs to freshwater area (inside the SMTS) and 2/3 is affected by sea water intrusion (outside the SMTS) and tidal movement from the East Sea through Hau river as indicated in Figure

6.1. Seasonal calendar in Zone 2 is presented as Figure 6.3. Sugarcane is dominant in this Zone and accounted for about 60% of total land area. Besides, other rice based farming systems are found in irrigated areas and high elevation land like 2 rice, 1 rice and 1 upland crop, or intensive upland crops. Animals are kept at family scale and mainly for household consumptions.



Note: HYV = high yielding varieties, UC = upland crops

Figure 6.3: Seasonal calendar of major farming patterns and hazards in Zone 2

Major hazards in Zone 2 consist of salinity intrusion, tidal flood, drought and storm (seldom). The period of salinity intrusion and drought are between December and May while tidal influence (causing flooding) affects the area from September to March every year. From January to April is the most stressful period for crop protection in this zone because of multiple perturbations. It is just the time for starting a new sugarcane crop but many hazards often occur at peak levels. Rainy season stops from December while salinity concentration in water gets higher and higher until it reaches the highest point in April. Besides, sluice gates under the SMTS are closed to protect rice crops thus freshwater source is cut off. As result, the water level outside the SMTS climbs up. These threats are more stressed in the dry years. During the last 15 years, the salinity level was highest in 1998 and lowest in 2000 (see Chapter 5 for details). The maximum salinity concentration was recorded at Vam Buon station (around 30 km from the sea) at 13.9 g/l in April 1998 while it was lowest in March 2000 as 4.4 g/l (Sam, 2006). In 2011, this figure was 9.5 g/l (Figure 6.1). Both sea water intrusion and drought (freshwater scarcity) affect more than 500 hectares of sugarcane and 300 hectares of upland crop production annually (Expert interview, 2010). In addition, tidal flooding affects sugarcane by plant collapse, more sensitive to pests, quality reduction, production cost increases whereas yield and price declines as shown in Table 6.3.

Table 6.3: Effects of tidal flooding on sugarcane production in Zone 2

Parameters	Normal field	Affected field	Increase (+)/Decrease (-)
Yield (kg/cong)	12,000	10,000	- 2,000
Selling price (VND/kg)	1,000	900	- 100
Costs for fertilizers and pesticides (VND/cong)	1,500,000	2,000,000	+ 500,000
Harvesting cost (VND/cong)	1,000,000	1,200,000	+ 200,000

Note: cong = 1,300m^2; VND = Vietnamese currency (1EUR equal to 23,000 VND in 2009)

6.2.3 Aquaculture zone

Aquaculture zone (Zone 3) located outside of the SMTS has an area of 3,500 ha and belongs to saline affected area. Due to its location, the salinity intrusion and tidal influences are greater than in Zone 2. The maximum salinity concentration was recorded at 23.1 g/l at La Bang station – around 15 km from the sea – in April 2011 (Figure 6.1). In the past, Zone 3 had rich natural fish/shrimp for catching and people mainly relied on such resources. Since 1990s, tiger shrimp has been introduced in this zone with higher and higher intensive input levels (shrimp density, chemical use, feeding, etc). Current seasonal calendar is presented in Figure 6.4. The rice-shrimp integrated farming system is popular here. Farmers grow rice in the wet season based on rainfall and cultivate tiger shrimp in the dry season. Shrimp monoculture with higher intensive level compared to rice-shrimp system is also found in some areas where the infrastructure is good and farmers have better financial capital.

The PVA results at community level showed that shrimp diseases are the most important hazard causing threats to people livelihoods. According to data from DARD-TV (2010), out of 853 shrimp farmers in Tra Cu, there were 220 farmers lost their production because of shrimp diseases. Beside shrimp diseases, if the rain stops early and salinity levels increase, the rice production is at risk of being lost. The HHS (2010) revealed that 14% of farmers have experienced this risk that not only declined rice yields (65%) and prices (28%) because of quality reduction but also increased costs (10%) due to more in investment inputs. Moreover, tidal flooding has been increasing in term of higher water levels and longer period that can destroy protected areas where private dykes have been built (see coping and adaptation in section 6.4 for details). It is also reported that during the closed-gate period the inundation becomes more serious for the other side of the SMTS as recorded in Zone 2.

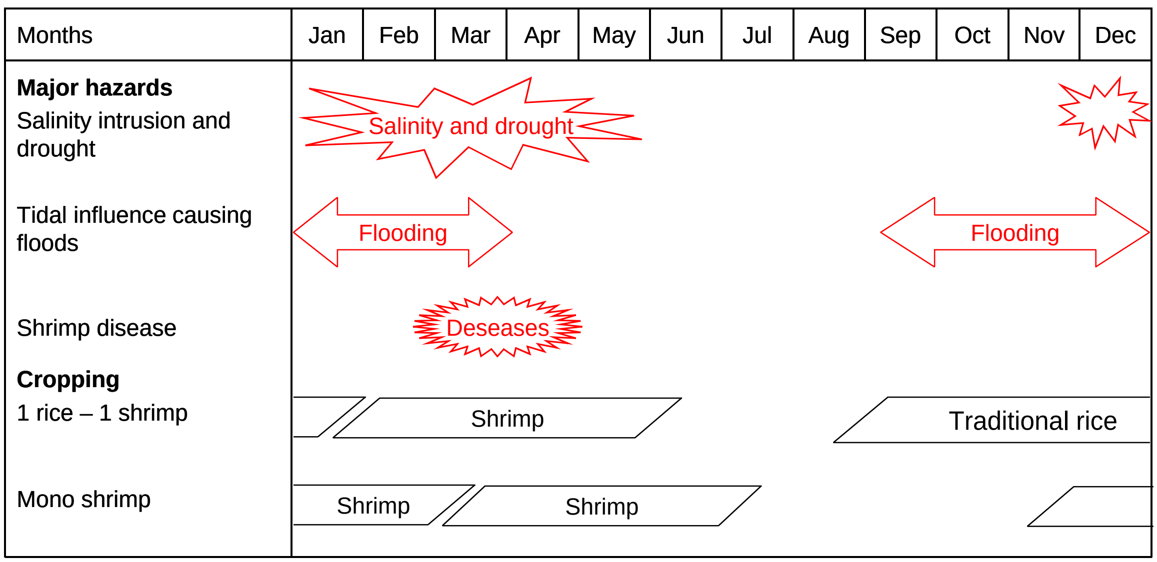


Figure 6.4: Seasonal calendar of major farming patterns and hazards in Zone 3

In short, the research sites have been exposed to different salinity levels depend on their natural-social characteristics. Zone 1 is freshwater control (inside of the SMTS) suitable for intensive rice production but still deals with freshwater scarcity and salinity leakage problems in the dry season. Zone 2 is characterized by sugarcane cultivation and affected by salinity intrusion and tidal flooding because part of the area is located outside of the SMTS. Zone 3 is also situated outside of the SMTS thus salinity and tidal flooding problems are recorded like in Zone 2. Most important that shrimp diseases are considered as the most dangerous hazard in this aquaculture zone. Recently, the hazards tend to increase in terms of frequency and intensity due to abnormal weather along with upstream flow alteration. In addition, in view of sea level rise the whole area will be strongly affected because of its low topography. Besides, under climate change storms and whirlwinds, which are seldom in occurrence now, will increase in the future. All of these will cause more hazard for coastal communities. However, the levels of vulnerability are different from community to community as well as from people to people depending on their conditions. The next section will focus on susceptibility in order to have a better understanding of vulnerability of different social groups in the study area to salinity related hazards.

6.3 Susceptibility

Although Tra Cu has achieved considerable results in terms of agricultural and socio-economic development thanks to many projects and programs from governmental organizations as well as non-governmental organizations it is still one of the poorest districts in the Mekong Delta. Its vulnerability to hazards and climate change results from many factors; with focusing on poverty rate, proportion of ethnic Khmer, land property arrangements, education levels, income sources and market changes. Table 6.4 presents the characteristics of groups with higher vulnerability and higher capacity in Tra Cu district. These criteria provide a basic understanding of vulnerability that helps to select proper indicators to construct vulnerability index to salinity intrusion. Poverty and vulnerability are different concepts but they are strongly linked. The poor are often more vulnerable to hazards. In the research site, the poverty rate is higher in villages with a high Khmer population. In 2009, the average poverty rate of Tra Cu was 32.7 per cent but in the Khmer population it was 72.6 per cent (TCSO, 2012). Reasons include no or limited land ownership, low education, and unskilled labor population, low agricultural production due to low technical application and investment, human diseases, many children per family, weak sanitation and hygienic conditions, few social networks, and more debts with high interest rates (outside the formal credit system) in the Khmer population. For instance, the illiteracy rate of household head in the survey showed that it was 13.1% in the Kinh (also called Vietnamese) whereas 25.1% in the Khmer groups (HHS, 2010). The main income sources of the poor are unskilled off-farm and non-farm wage labor (i.e. mason, house-keeper, stevedore, pesticide sprayer, harvestman, etc). The jobs are exhausting but irregular, seasonal and provide only a low income (even fewer for female). Therefore, the income flow is not constant during the year. In times of unemployment they have to borrow money and most cases from local lenders at a high interest rate. As a result, the poor get poorer and the gap widens between poor and rich. These are supplemented by the HHS results that total income per household is significantly different between the Kinh and Khmer, the better-off and the poor, as well as the male and female groups (Table 6.5).

Table 6.4: Characteristics of higher vulnerability and higher capacity groups in Tra Cu

Criteria	Groups with higher vulnerability	Groups with higher capacity
Major income sources	Wage labor, fishing, agriculture	Agriculture, aquaculture, business, official salary
Jobs	Off-farm and non-farm, seasonal	On-farm, official, regular
Economic status	Poor or medium, less assets	Better-off, more assets
Loan sources	High ratio of debt over total income, most from informal credit systems with high interest rates	Low ratio of debt over total income, most from formal credit systems with suitable interest rates
Market	Less opportunities to access	More opportunities to access
Ethnicity	Khmer	Vietnamese (Kinh)
Gender	Female	Male
Education	Low education, unskilled labor	High education, skilled labor
Dependency population	Higher, more children and ill people	Lower, less children
Social network	Few opportunities to build social network, language barrier	More opportunities to build social network
Land	Landless or small piece of land, less fertile, non-sophisticated irrigation	Bigger areas, more fertile, good irrigation
Dykes	Outside SMTS and other public dykes then more vulnerable to salinity and tidal floods	Whether inside public dyke systems or higher resources to build own dykes to mitigate the hazards
Housing location	Open fields, far from roads	Next to roads, good transportation
Drinking water	From river/pond, well, rain	Bottled, piped, rain, well
Hygiene	Fishpond toilets	Double vault composting latrines

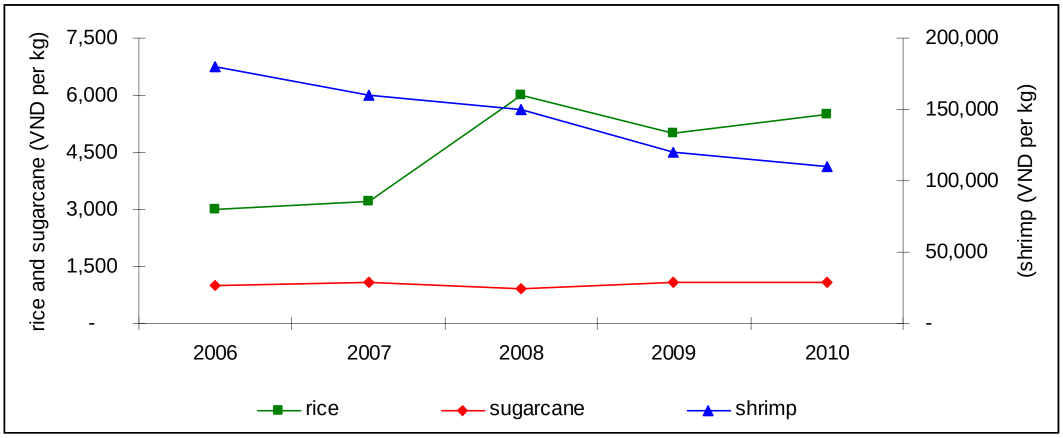
(Drawn from PVA in Tra Cu)

Table 6.5: A comparison of income per household in 2010 by different social groups

	Social groups	Number of respondents	Income per household (million VND)
By ethnicity	Kinh	237	43.1
	Khmer	275	34.1
	Total/Average	***512***	***38.3***
	P-value (t-test)		*0.004*
By wealth	Better-off	375	45.1
	Poor (with certificate)	137	19.6
	Total/Average	***512***	***38.3***
	P-value (t-test)		*0.000*
By gender	Male	426	39.8
	Female	86	30.8
	Total/Average	***512***	***38.3***
	P-value (t-test)		*0.035*

(Household survey, 2010)

The income and livelihoods of people are highly dependent on agricultural production and market prices. In recent years agricultural production has not (or slowly) increased but higher production costs have occurred because of bad weather, crop diseases and high input prices. However, agricultural product prices are unstable and even have the tendency to decrease. As a result, the livelihoods are affected. In terms of risk, Zones 2 and 3 are more susceptible to market changes as sugarcane and shrimp prices are more unstable as compared to rice prices (Figure 6.5). Besides, shrimp diseases and environmental pollution have become big issues for aquaculture in Zone 3. It also notes that agricultural risks in Tra Cu have strong relationship with dyke situation for crop protection from salinity intrusion and tidal floods. People who are located inside the public dyke systems like the SMTS are less vulnerable to such hazards. In case of outside the public dykes, but better-off farmers can reduce crop damages by building a dyke surrounding their own fields while the poor can not pay for such expensive investments. Details of coping and adaptation strategies of local people including dyke construction will be discussed in the following section.



Note: price at farm; VND = Vietnamese currency (1EUR equal to 23,000 VND in 2010)

Figure 6.5: Price trend-lines of major agricultural products in Tra Cu district

6.4 Coping and adaptation strategies

To cope with and adapt to salinity intrusion and related problems, the government and local people have many strategies and actions such as dyke buildings, crop calendar adjustments, changes in species and varieties, more input investment, agricultural supporting policies, water storage and groundwater exploitation, income diversification and government policies for vulnerable groups.

6.4.1 Dyke buildings

Dyke construction is one of important adaptation strategies to salinity intrusion for agricultural development in the coastal regions. Besides “big projects” like the SMTS which was planned and built by the central government, many “smaller projects” (about hundreds ha) have been implemented to prevent sea water intrusion and tidal influence in the research area. These smaller projects are funded by the province and/or district. At high risk areas as Zone 2 and 3, farmers have also protected themselves by building individual dykes around their fields. The fixed costs for these investments are estimated about 15 to 20 million VND per ha and the expenses for operation and maintenance are about 4 to 5 million per ha per year. Therefore, they are very costly and often suitable for the better-off groups while the poor groups cannot afford to install such options. Generally, the dyke systems have shown many advantages as intensification and diversification in agriculture, freshwater supply for domestic uses, rural transportation development, tidal influence reduction; however, they have also caused negative impacts such as increasing water levels outside the dyke areas, reducing natural fish resources, pollution due to water stagnancy, declining soil fertility, being of risks as leakages and dyke damages, losing land for construction (Table 6.6). During the PVA surveys, local people reported that before the construction of sluice gates and dyke systems natural fish resource was abundant and contributed a significant part to total household income, especially landless and poor people. Estimation from the key informant interview (2009) in Zone 1 showed that in 1990s, fishing activity contributed around 15% of total household income; the contribution is now only 1%. During closed sluice gate period, the crops inside the dykes are protected from salinity intrusion but it causes serious inundation in the other side of the dykes. Particularly in 2005, the outside areas could not cope with the high water level, and the sluice gates had to be opened to avoid catastrophic failure. Hence, it is necessary to develop more effective strategies to minimize the disadvantages of dyke systems, especially for affected communities located in the other side of the dykes.

Table 6.6: Advantages and disadvantages of dyke construction for salinity control in Tra Cu

Reasons for advantages and disadvantages		Frequency	Percentage	Ranking
Advantages	Crop (rice) intensification	165	43.9	I
	Agricultural diversification	86	22.9	II
	Freshwater for domestic uses	71	18.9	III
	Rural transportation development	20	5.3	IV
	No inundation, tidal influence reduction	19	5.1	V
	Others	15	4.0	VI
	Total	***376***	***100.0***	
Disadvantages	Increasing water levels outside the dykes	87	37.2	I
	Reducing natural fish resources	47	20.1	II
	Pollution due to stagnant water	37	15.8	III
	Declining soil fertility inside the dykes	24	10.3	IV
	Being of risks (leakages, dyke damages)	15	6.4	V
	Losing land for construction	12	5.1	VI
	Others	12	5.1	VI
	Total	***234***	***100.0***	

(Household survey, 2010)

6.4.2 Crop calendar adjustments

Seasonal calendar adjustments in crop farming are common way to deal with salinity intrusion and freshwater scarcity in the lower Mekong delta. Based on experience, sluice gate operation schedule from the Irrigation Company and the seasonal calendar from the Department of Agriculture and Rural Development (DARD), farmers have adjusted their calendar crop by crop. For example, if the rain comes later they will seed later and vice versa. But this sometimes can put people at risk due to abnormal weather (i.e. a shorter rainy period, earlier salinity intrusion). Moreover, later seeding in one crop will affect the following crops; especially with three rice cropping system (see section 6.2.1 for detail). Thus, it is necessary to improve the weather forecast system, salinity monitoring by using both modern technologies and indigenous knowledge.

6.4.3 Changes in species and varieties

Choosing suitable crops, species and varieties for each socio-ecological system are interested in some past decades. In freshwater scarcity areas or high elevation land instead of rice farming, farmers select other crops which need less water than rice such as maize or vegetables. In Zone 2, traditional rice was popular in the past but it is replaced by sugarcane that can grow better than rice under higher salinity and water level. Not only crop but also variety have been changed, for example, varieties with shorter duration and tolerant to higher water level have been experimented in sugarcane farming.

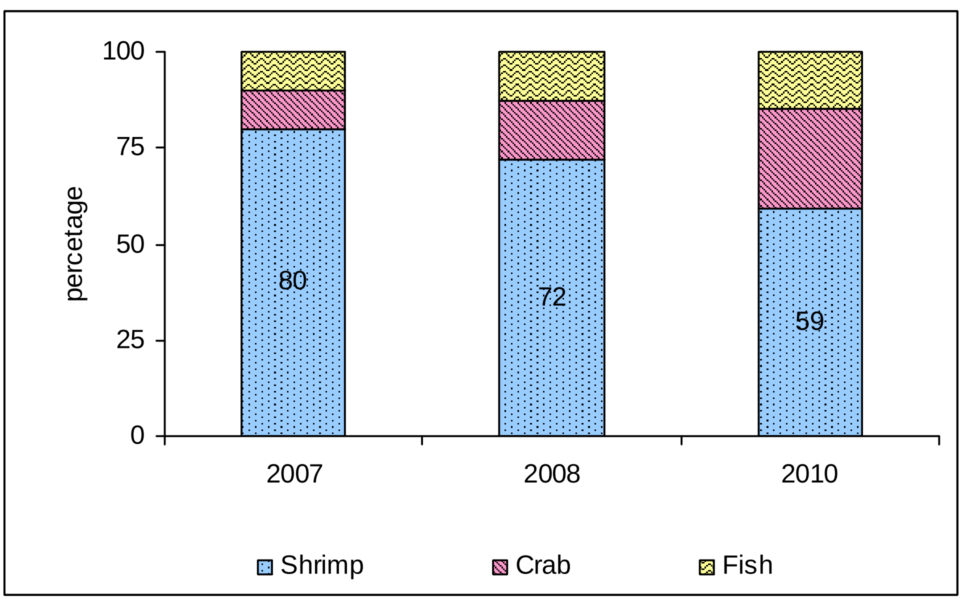


Figure 6.6: Shifts in aquaculture production in the coastal areas (outside of SMTS) of Tra Vinh

(Based on data from DARD-TV, 2010)

In aquaculture area (Zone 3), before the 1990s farmers grew only one traditional rice crop in the wet season but later on they introduced shrimp in the dry season. In recent years, shrimp farming has faced diseases and environmental pollution. To cope with the situation, some farmers culture crabs or other fish species instead of shrimp. Secondary data from DARD confirms that a proportion of shrimp to total aqua-products has been declined whereas crabs and fish increased in the last years (Figure 6.6). Integrated rice-shrimp farming is a suitable system in coastal areas (Binh et al. 2009). Therefore, it is important to do more research on this farming in order to diversify agricultural activities and utilize land and water resources in saline affected areas.

6.4.4 More input investments

Farming technical applications like reseeding, re-transplanting, more fertilizer and chemical uses are common methods to cope with the hazards. If plants or animals are affected at the beginning of cropping calendar then farmers can reseed or refill them. In case the hazards occur during growth period of crops, fertilizers, stimulants or/and other chemicals are applied to foster their development after the shocks. Damaged areas can also be replanted by gathering plants at the same age from other plots. However, these coping options always increase labor uses and production costs. For example, the additional costs for such input investments were estimated about VND 2 million per ha per crop for rice and VND 10 million per ha per crop for sugarcane (PVA, 2009). Therefore, in many cases profits are little or negative.

6.4.5 Agricultural supporting policies

There are some policies from the government like seedling, chemical, credit and cash supports to help farmers recover what were lost by disasters. For example, implementation of Prime Minister Decision No 142/2009/QD-TTg about supporting producers in affected areas by natural hazards above 2,000 rice farmers in Tra Cu who had been impacted by drought/salinity intrusion in 2010 received 1.1 billion VND. Similarly, 9,673 rice farmers have been assisted 7.1 billion VND in 2011 (DARD-TC, 2011). Farmers received cash depending on levels of damage. Half of million VND for damage level from 30 – 70 % and 1.0 million VND for damage level over 70%. It is to be noted that most of these aids focus on rice whereas upland crops and sugarcane get little attention. The supports should cover not only rice but also other crops to create a fair spread of aid among different farmer groups in affected regions.

6.4.6 Water storage and groundwater exploitation

Traditionally rainwater storage and exploitation of groundwater are common ways to deal with freshwater scarcity in the coastal regions. In the wet season, farmers harvest and store rainwater in jars or small tanks in order to use it in the dry season, mostly for drinking and cooking. For other types of household consumption, people use groundwater from individual drilled wells or rural tap water supply systems which are newly developed. Along the sand ridge areas, groundwater is also exploited for watering upland crops. In the 1990s, many handle wells were drilled under a UNICEF program. According to the Department of Natural Resource and Environment, there are more than 14,000 drilled wells in Tra Cu today. Currently, the use of groundwater is free of charge which could cause excessive exploitation in the near future. Thus, research on groundwater markets is necessary for better management of this resource in the region.

6.4.7 Diversification of income sources

Diversification of income sources can help to reduce weather related risks and socio-ecological changes that are popular adaptive strategies in the research region. Before the SMTS was built, natural fish resources were considered as a source of income for local people, especially the poor. However, after the construction of the SMTS, natural fish stocks were reduced which affects mainly the poor people who have previously relied on open access, common pool, natural fish resources. Crop failures due to water related hazards have caused many difficulties to people’s livelihoods. On the other hand, local industrial activities have not much developed but rural labor is increasing due to population explosion. Therefore, a number of young people have moved to cities (e.g. Ho Chi Minh City, industrial zones in South East Vietnam) to find new jobs since late 1990s. It is estimated that around 10% of total population have migrated out the district (own expert interview, 2009). Recent years, traditional handicraft careers are concerned in the villages and create some incomes for local people. Diversifications in agricultural sector like new crops, species and varieties or new farming systems are also paid more attention. Besides, the central government has approved the Dinh An Economical Zone which include many sectors as industry, commerce, service, tourism, agriculture, forestry, fishery associated with the marine economy. It is expected that the Dinh An Zone will generate more jobs and incomes for the coastal communities of Tra Vinh province.

6.4.8 Adaptation of vulnerable social groups

As mentioned, the Khmer population in the region shows relatively high poverty rates when compared to other groups. Household livelihood activities differ between wealth groups. The poor rely much on unskilled off-farm and/or non-farm wage labor due to their low education levels. The government has many policies to reduce poverty among such population (i.e. the Prime Minister Decision 135/1998/QD-TTg, also called "135 Program" for improving infrastructure and living conditions in disadvantaged communities, the Prime Minister Decision 134/2004/QD-TTg, also called "134 Program" for supporting land, houses and tap-water in minority ethnic population, etc). However, they do not seem to be very effective and stable due to their single disciplinary and top-down approach that did not include stimulating community participation and empowerment. People just above the poverty line can easily fall below that line if they suffer from shocks such as human diseases or crop failures. It is necessary to develop more effective measures and increase investment for rural poor areas (i.e. extension, training and education, micro-credit, job creation, health care programs). The way to set up such programs should change from the current "top-down" approaches towards an inclusion of participatory and multi-disciplinary components in order to make them more useful and stable. Lessons learnt from this study showed that the PVA approach can be suitable to develop adaptation strategies in the study area. The active participation of communities helps to recognize real problems and challenges effecting their productions and livelihoods. Through PVA the roots causes of vulnerability and adaptive capacities of different groups are identified. Therefore, it will be helpful to develop action plans to make use of local resources whereas minimizing the hazard impacts in varying social-ecological settings. By participatory approach, local people are involved and perceived as "insiders" instead of "outsiders" as top-down manner then they will play active role during adaptation process.

6.5 Conclusion

The findings from the PVA surveys show that agricultural activities and living conditions in the study site have been affected by many water related hazards such as salinity intrusion, shortage of freshwater, shrimp disease and tidal influences, especially in the dry season. Vulnerability to such hazards results from many different factors, not only in terms of socio-economic factors but also due to close coupling processes within social-ecological systems. Many adaptation strategies and measures have been developed by government and local people (e.g., dyke buildings, crop calendar adjustments, groundwater exploitation, agricultural supporting policies, income diversification, etc.) to cope with and adapt to such hazards. However, current adaptation options have shown some limitations because they do not fully consider the differences in terms of ecological, social and economic environments. These sometimes lead to conflicts; for example, freshwater users for crop farming and brackish water users for shrimp farming, benefit from dyke building. As land owners they can increase crop production but building of dykes has reduced the natural fish resources which the poor farmers rely on. The dyke systems cause socially differentiated effects as people inside the system benefit while people outside the system are affected by increased occurrence of flooding. Besides, most of these measures proposed or currently in place do not consider climate change in the long-term. According to Dixon et al. (2001), diversification is a potential measure against bad weather and marketing risks. Lessons learned from adaptation strategies in Tra Cu showed that diversification of income sources including on-farm, off-farm and non-farm activities plays an important role in improving people’s livelihoods. The main concerns here are what to diversify (whether on-farm, off-farm, and/or non-farm options) and how to deal with tradeoffs between them in different ecological, social and economic conditions. Therefore, it is necessary to apply a suitable approach (i.e. holistic and multi-disciplinary approach) for future adaptation strategies that can benefit different social groups especially the most vulnerable like the poor, Khmer, and people outside the dykes. This is to be done within the context of climate change and sea level rise for coastal communities in the Mekong delta.

Chapter 7: MEASUSING VULNERABILITY TO SALINITY INTRUSION IN THE MEKONG DELTA BY COMPOSITE INDICATORS

7.1 Introduction

From the participatory vulnerability analysis in Chapter 6, lots of information and qualitative data were collected and we knew that people vulnerability to salinity intrusion is shaped by many factors due to interrelation of rural social-ecological systems; however, it is difficult to conclude which ecological zones (i.e. freshwater or brackish water) and social groups (i.e. Kinh or Khmer people) are the most vulnerable to the hazard in order to develop interventions and policies for risk reduction purpose. Thus, there is a need to build up a quantitative approach to measure vulnerability among different groups. In this chapter, the results of measuring vulnerability to salinity intrusion by composite indicators will be presented based on quantitative data obtained from the household survey in the study area. The vulnerability index was constructed based on three major elements as exposure, susceptibility, and capacity sub-indices (see Chapter 3 for details of methodology). By this approach, total vulnerability to salinity intrusion will be measured and compared in different contexts such as ecological zones and ethnic groups.

7.2 Index development

7.2.1 Conceptual framework

This study applies the BBC conceptual framework that encompasses three major elements of vulnerability concept as exposure, susceptibility and capacity capturing three pillars of sustainable theory including social, economic and environmental aspects (Birkmann, 2006; 2013). According to many authors, the social, economic and environmental spheres cannot be separated under sustainability as well as vulnerability analyses because of the mutuality between human beings and the environment (Birkmann, 2006 p35; Renaud, 2006: p117). Therefore, in this research the salinity intrusion vulnerability index will be developed based on three sub-indices like exposure sub-index (ESI), susceptibility sub-index (SSI), and capacity sub-index (CSI) with different groups in various rural social-ecological systems in the Mekong delta of Vietnam (Figure 7.1). By doing this, the index will demonstrate which groups are the most vulnerable to the hazard with regard to the system’s dimensions such as social, economic and environmental.

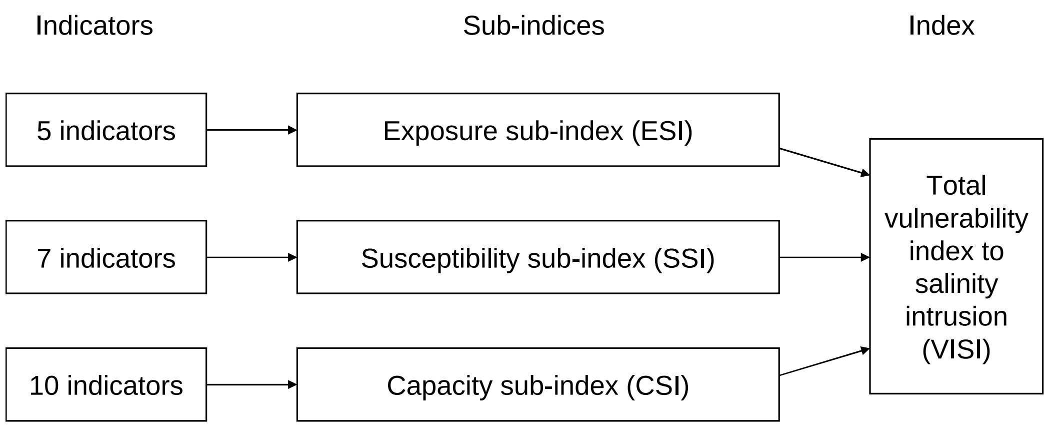


Figure 7.1: Hierarchical indicator framework for vulnerability assessment to salinity intrusion

7.2.2 Selection of indicators

The components of vulnerability index that have been linked with the three elements of vulnerability concept can be developed and assessed by using different indicators. Generally, indicators can be selected through inductive or deductive approach. In this study, the deductive approach has been employed to identify the best possible indicators thanks to its advantages for social sciences such as simple, realistic, hazard context, cheap, etc, (Yoon, 2012).

There are two main steps for the selection of indicators. First, based on review of existing literature, field observation and participatory vulnerability analysis from the study sites (see Chapter 6, particularly Table 6.4) twenty indicators are selected. Second, this indicator list was sent to fourteen experts in Can Tho University (eight from the Mekong Delta Development Research Institute, two from the Climate Change Institute, two from the College of Rural Development, and two from the College of Environment and Natural Resources Management) who have good knowledge in vulnerability assessment as well as rural development in the Mekong delta. They were asked to advise ten indicators for measuring vulnerability to salinity intrusion whether in the list of mentioned indicators or not according to their perception. Three more indicators were added but one of them relate to the identical indicators (i.e. education level of household head may include in illiteracy indicator). Thus, there are the total of twenty two indicators are selected; of which, five indicators for hazard exposure, seven indicators for susceptibility and ten indicators for capacity. After indicator selection, a household survey with 512 interviewees representing in different social-ecological systems in the study area was conducted to collect the mentioned indicator data.

Table 7.1: The relationship between vulnerability dimensions, elements, and indicators

Dimensions	Elements	Indicator name	Abbreviations	Relationship to vulnerability
Environment	E1	Number of hazards	NOH	Increase
Environment	E2	Effects of salinity intrusion	EOS	Increase
Environment	E3	Effects of tide	EOT	Increase
Environment	E4	Effects of drought	EOD	Increase
Economic	E5	Crop damage ratio	CDR	Increase
Social	S1	Chronic illness ratio	CHR	Increase
Economic	S2	Health cost income ratio	HCR	Increase
Economic	S3	Debt to total income	DTI	Increase
Economic	S4	Crop income ratio	CIR	Increase
Social	S5	Dependency ratio	DER	Increase
Social	S6	Illiteracy ratio	ILR	Increase
Economic	S7	Wage income ratio	WIR	Increase
Economic	C1	Income per capita	IPC	Reduce
Economic	C2	Saving per capita	SPC	Reduce
Economic	C3	Number of income sources	NIS	Reduce
Social	C4	Health insurance ratio	HIR	Reduce
Economic	C5	Basic asset values	BAV	Reduce
Social	C6	Number of received trainings	NRT	Reduce
Environment	C7	Number of water sources	NWS	Reduce
Environment	C8	Total land area	TLA	Reduce
Economic	C9	Protected land area	PLA	Reduce
Social	C10	Working outside of community	WOC	Reduce

Note: E = exposure, S = susceptibility, C = Capacity

Table 7.1 summaries vulnerability indicators and their relationship to vulnerability dimensions (social, economic and environmental) as well as vulnerability elements (exposure, susceptibility and capacity). It is necessary to note that some of the indicators can belong to more than one of the vulnerability elements. To simplify, the indicators which increase vulnerability are considered as susceptibility and exposure while the indicators which reduce vulnerability belong to capacity category (Table 7.1).

7.2.2.1 Indicators for hazard exposure sub-index

Hazard exposure is the likelihood of individual, household, community, state or ecosystem experiencing the environmental stresses which are characterized by frequency, magnitude and duration of the hazards (Turner et al., 2003; Adger, 2006). For the purpose of vulnerability assessment to salinity intrusion in the rural socio-ecological context in the Mekong delta, five indicators are identified for exposure sub-index (ESI).

- Number of hazards (NOH, hazards): It means that total number of natural hazards affected the household livelihood in the past five years. More hazards suggest more environmental vulnerability.
- Effects of salinity intrusion (EOS, 1-5 scale evaluation): Severity level of salinity intrusion was reported by the households using 1-5 scale evaluation, with higher value being worse.
- Effects of drought (EOD, 1-5 scale evaluation): Severity level of drought was reported by the households using 1-5 scale evaluation, with higher value being worse.
- Effects of tide (EOT, 1-5 scale evaluation): Severity level of tide was reported by the households using 1-5 scale evaluation, with higher value being worse
- Crop damage ratio (CDR, %): The ratio of the crop damaged areas to the planted areas. More damaged areas show that more exposure to hazards causing heavier loss then higher vulnerability.

7.2.2.2 Indicators for susceptibility sub-index

Susceptibility describes the characteristics that render persons or groups of people generally weak or negatively constituted against stresses and threats (Fekete, 2010). It has a close relationship between exposure and susceptibility within a system because the relative effect of exposure on a system is dependent on the relative susceptibilities. There are many related indicators which can be negatively affected by coastal hazards in the Mekong delta. In this vulnerability assessment study, seven indicators are employed to calculate susceptibility sub-index (SSI).

- Chronic illness ratio (CHR, %): Ratio of chronically ill people to total family members. The chronic illness was defined subjectively by the respondents. The signal for this indicator is that higher is worse.
- Health cost income ratio (HCR, %): Ratio of health costs to total income. More costs for health mean more susceptible.
- Debt to total income ratio (DTI, %): It is the ratio of debt to total income. This value is higher that means higher susceptibility.
- Crop income ratio (CIR, %): The indicator is percentage of income from crop farming to total household income. More of total income coming from crop production suggests a higher vulnerability to salinity intrusion because crops are often sensitive to salt water.
- Dependency ratio (DER, %): Ratio of the population under 15 and over 65 years of age to the population between 15 and 65 years of age. Higher dependency ratio implies higher susceptibility.
- Illiteracy ratio (ILR, %): Percentage of adult population that can't read and write. Higher illiteracy ratio is higher susceptibility.
- Wage income ratio (WIR, %): The indicator is percentage of income from wage labor that is seasonal and unskilled jobs to total household income. The higher wage income ratio means higher susceptibility.

7.2.2.3 Indicators for capacity sub-index

Adaptive capacity is the ability to design and implement effective adaptation strategies that depend much on resource availability and accessibility such as natural, financial, institutional, human resources and social networks (Brooks and Adger, 2004). With in the context of rural social-ecological system in the coastal areas of Mekong delta, ten indicators are identified to construct capacity sub-index (CSI).

- Income per capita (IPC, Vietnamese Dong): This indicator is calculated by the ratio of total household income in the survey year to total family members. More income generated per capita is higher adaptive capacity to the hazard.

- Saving per capita (SPC, Vietnamese Dong): It is total income per capita after deducting total expenses. The higher saving means that higher adaptive capacity to stresses and threats.
- Number of income sources (NIS, income sources): This indicate that how many income activities exist in the household. The signal for this indicator is that higher is better.
- Health insurance ratio (HIR, %): Percentage of family members who own health insurance card. Higher insurance ratio means stronger coping capacity.
- Basic asset values (BAV, Vietnamese Dong): This is the values of key assets that often include houses, farming tools, motorbikes, computers, freezers, television, and other furniture. The basic asset values here exclude land's property. If the households own more assets they have better capacity to adapt that means ultimately lower vulnerability.
- Number of received training (NRT, training): Number of trainings that family members received mainly through extension services. More training is higher adaptive capacity.
- Number of water sources (NWS, water sources): It means that total number of water resources the household have accessed for drinking, cooking and washing purposes. Less accessibility to water sources is less capacity.
- Total land areas (TLA, ha): This indicates that how many hectares of land belong to the household. More access to land property suggests lower vulnerability.
- Protected land area (PLA, %): It is percentage of land areas was protected either by public construction measures (dykes and sluice gates) or private ones to salinity intrusion and/or tidal effects. Higher is better.
- Working outside of community (WOC, %): Percentage of family members working in a different community. Higher working outside of community ratio is better.

7.2.3 Normalization

Normally, the indicators in a data set often have different measurement units. Then normalization is required to render the variables comparable (OECD, 2008). There are a number of methods for normalizing values of disparate units. One of the most notable is the normalization procedure applied for the Human Development Index (called Min-Max method), calculated annually by the United Nations Development Program (Swanson et al., 2009). This method normalizes indicators to have an identical range (0, 1) by subtracting the minimum value and dividing by the range of the indicator values (OECD, 2008).

In the context of vulnerability assessment, the Min-Max normalization method was applied in many cases around the world at different scales including household level; for example, Patnaik and Narayanan, 2005; Swanson et al., 2009; Hahn et al., 2009; Balica et al., 2012. For the purpose of measuring vulnerability to salinity intrusion in this study, the Min-Max method is used for normalizing each identified indicators as Equation 1 (based on OECD, 2008).

$$\text{Normalized value} = \frac{(\text{Value to be normalized} - \text{Minimum value})}{(\text{Maximum value} - \text{Minimum value})} \qquad \text{Equation 1}$$

7.2.4 Calculation of sub-indices and index

After normalization, the sub-indices and total index are calculated without weighting because of "different number of rating judgments which lie behind combined weights or interpolating" (Balica et al., 2012). Based on this assumption of equal importance, each element of vulnerability is calculated by an average of normalized values of the identified indicators. Whereas, the total vulnerability is calculated by subtracting capacity from exposure and susceptibility (ABARE-BRS, 2010). Thus, the equations for the calculations of the exposure, susceptibility, capacity sub-indices and overall vulnerability index are expressed as Equation 2 to 5 respectively. By this approach, the sub-indexes give a number from 0 to 1, and the total vulnerability index ranges from -1 to +2 indicating comparatively low or high vulnerability elements to salinity intrusion.

Exposure Sub-Index (ESI)	$=$	$\sum (E_i)/i$	Equation 2
Susceptibility Sub-Index (SSI)	$=$	$\sum (S_j)/j$	Equation 3
Capacity Sub-Index (CSI)	$=$	$\sum (A_k)/k$	Equation 4
Vulnerability Index to Salinity Intrusion (VISI)	$=$	ESI + SSI - CSI	Equation 5

Whereas E_i is the value of indicator (i) for exposure, S_j is the value of indicator (j) for susceptibility and A_k is the value of indicator (k) for capacity.

7.2.5 Statistical analysis

7.2.5.1 Multivariate analysis

Multivariate analysis is used to study the overall structure of the dataset, assess its suitability, identify groups of indicators that are statistically similar and provide an interpretation of the results (OECD, 2008: p20). There are many ways to carry out multivariate analysis when constructing composite indicators such as principal components or factor analysis, Cronbach coefficient alpha, cluster analysis, correspondence analysis, canonical correlation analysis, etc (detail in OECD, 2008). Among them the most commonly use for vulnerability index construction is factor analysis technique (Rygel et al., 2006; Fekete, 2010; ABARE-BRS, 2010). A factor analysis is employed in this study to assess overall structure of dataset and summarize a small set of individual indicators for vulnerability index construction that represents the underlying relationships among a group of related variables without losing too much information. The software used was “IBM SPSS Statistics 20” following standard procedure (i.e. Pallant, 2001).

Step 1: Assessment of the suitability of the data for factor analysis

- Number of cases: It is comforting to have at least 300 cases for factor analysis (Tabachnick and Fidell, 1996 in Pallant, 2001: p153). Other authors suggest “5:1 ratio”, that is five cases for each item to be factor analyzed (Bryant and Yarnold, 1995; Nunnaly, 1978; Gorsuch, 1983 in OECD, 2008: p66). In this study, there are twenty two individual indicators gathering from 512 households. Thus, the number of cases (512 responses) satisfies above standards.

- Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy are two statistical measures helping to assess the factorability of the data. The Bartlett's test of sphericity should be statistically significant at $p<0.05$ and the KMO should be 0.6 as minimum value for a good factor analysis (Pallant, 2001: p157). The KMO value in this analysis was 0.712 and the Bartlett's test of sphericity is significant (Table 7.2); therefore, factor analysis is appropriate.

Table 7.2: KMO and Bartlett's test for 512 cases with 22 indicators for vulnerability assessment

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.712
	Approx. Chi-Square	3305.559
Bartlett's Test of Sphericity	df	231
	Sig.	0.000

Step 2: Factor extraction

- Factor extraction involves determining the smallest number of factors that can be used to the best represent the interrelations among the set of variables. There are many approaches to extract the number of underlying factors. In this study, the principal component analysis which is the most commonly extraction technique was applied. To decide number of factors to retain in the model, there are two techniques as Kaiser's criterion and Scree-test (Pallant, 2001; OECD, 2008).
- The Kaiser's criterion or eigenvalue rule: The eigenvalue of a factor represents the amount of the total variance explained by that factor. This rule suggests that all factors with eigenvalue below one is dropped out.
- Scree-test: This method, proposed by Catell (1996), retains all factors above the "elbow", or break in the plot, as these factors contribute the most to the explanation of the variance in the data set (Pallant, 2001: p154).
- Figure 7.2 presents the scree plot of factor analysis showing the eigenvalue that suggests eight components with eigenvalue above one. From the plot, there is a

clear break between the second and third components. It also depicts another "elbow" after the seventh components. Therefore, the components remaining in the analysis should equal to eight or less than eight.

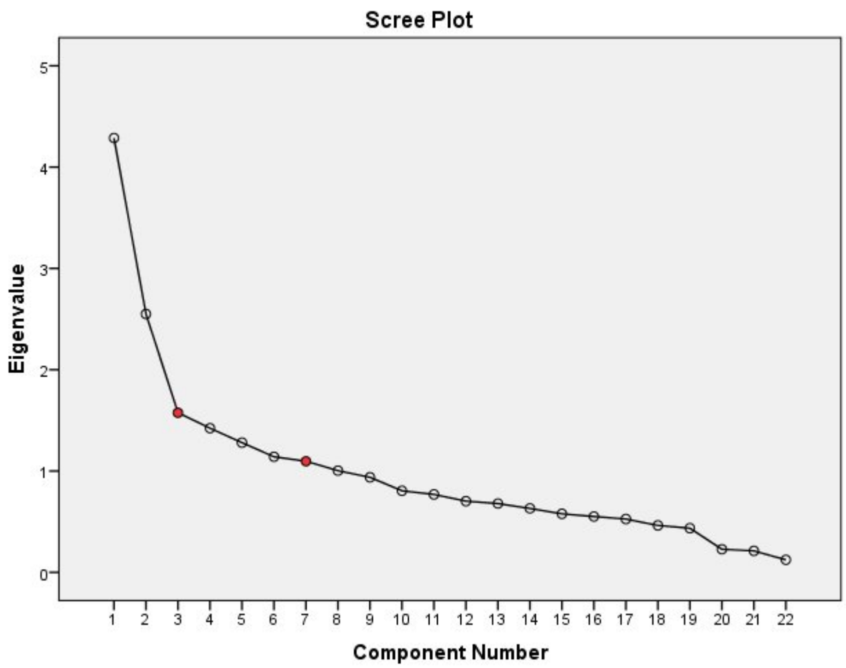


Figure 7.2: Scree plot of the factor analysis showing "two elbows" at the third and seventh components

Step 3: Factor rotation and interpretation

- After determining number of factors, the next step is interpret them. To assist in this process it is necessary to do factor rotation. This does not change the underlying solution, but rather it presents the pattern of loadings in a manner that is easy to interpret. Orthogonal rotation approach using Varimax technique, which attempt to minimize the number of variables that have high loadings on each factor was employed in this study because this is the most commonly used technique and tends to be easier and clearer to interpret (Pallant, 2001: p162).

- High and moderate loadings (above 0.5) indicate how the individual indicators are related to the principle component (OECD, 2008). With the eight identified components (eigenvalue bigger than one) in this study, all twenty two indicators have loading value after rotation above 0.5. From component 1 to 6, there are at least two indicators with loading value above 0.5 per component, whereas component 7 and 8 has only one indicator. Totally, the first two components include nine indicators, three components thirteen indicators, four components sixteen indicators, five components eighteen indicators, six components twenty indicators and eight components twenty two indicators (details in Table 7.4).

7.2.5.2 Sensitivity analysis

Sensitivity analysis aims to describe how much model output values are affected by changes in model input values (UNESCO, 2005: p265). From factor analysis, it suggests that the VISI index can be constructed by whether 22, 20, 18, 16, 13, or 9 indicators. The question is how many indicators should be the best. Perhaps too many and/or too few indicators is undesirable. Thus, a sensitivity analysis is undertaken in order to assess the robustness of the VISI with different numbers of indicators. Simple sensitivity analysis can be based on graph; for example, box-plot (Naumann et al., 2014). Then box-plot is used to assess the VISI index with many cases such as 22, 20, 18, 16, 13, and 9 indicators.

7.2.5.3 Two factor analysis of variance

As mentioned in Chapter 3, the household survey covers different social groups based on two factors such as ethnicity (Kinh and Khmer ethnic groups), ecological zone (Zone 1 dominated by rice farming, Zone 2 based on sugarcane, and Zone 3 indicated as rice – shrimp farming systems). Then a two factorial ANOVA (analysis of variance) was used to examine the main effects and interactions of two above independent factors, ethnic groups and the zones. Wherever ANOVA is found significantly difference, the Tukey post-hoc tests are employed to compare means of vulnerability sub-indices and total index (Trong and Ngoc, 2008). This analysis helps to identify the most vulnerable groups in the study areas.

7.3 Results and discussions

7.3.1 Characteristics of households

Key characteristics of households in the 2010 survey are presented in Table 7.3. Average age of the household heads is 51.6 years and not different among zones as well as ethnic groups. Average of household size ranges from 4.1 to 4.4 people per family. The statistical data also reported that on the average each family in Tra Cu district consists of 4.2 people (TCSO, 2012). There are difference in term of land area owned by household among three zones. In Zone 1, the land area is averaged about 0.86 ha per household, bigger than Zone 2 (0.61 ha) and Zone 3 (0.44 ha). This happens because of population density; for example, the population density in Tan Hiep commune of Zone 1 was only 424 inhabitant per km^2 compared to 460 in Luu Nghiep Anh commune of Zone 2 and 840 in Dai An commune of Zone 3 (TCSO, 2012). Between the Kinh and Khmer group, land area owned by households is not different. However, household incomes have big difference between such two groups; for example, VND 43.1 million per household per year in Kinh group compared to VND 34.1 million of the Khmer group. This provides useful information to examine the vulnerability of different social groups.

Table 7.3: Characteristics of households (HH) in the 2010 survey

Group		N	Age of HH head (year)	HH size (people)	HH land area (ha)	HH income (million VND/year)
By Zone	Zone 1	167	51.1	4.4	0.86	41.8
	Zone 2	172	50.2	4.1	0.61	43.7
	Zone 3	173	53.4	4.2	0.44	29.3
	Total	*512*	*51.6*	*4.2*	*0.63*	*38.3*
By Ethnicity	Kinh	237	52.0	4.2	0.62	43.1
	Khmer	275	51.2	4.3	0.65	34.1
	Total	*512*	*51.6*	*4.2*	*0.63*	*38.3*

(Household survey, 2010)

7.3.2 Multivariate analysis

From principal component analysis, there are eight components with eigenvalues exceeding one. Total variance explained by the components with initial eigenvalues and after rotation shows that the cumulative variances of eight components are the same for both cases, before and after rotation (65.3%) but the rotation affected variance of each component. For the initial eigenvalues, these eight components explain 19.5%, 11.6%, 7.2%, 6.5%, 5.8%, 5.2%, 5.0% and 4.6% of the variance respectively; whereas for the rotation case, component one to eight contribute 12.8%, 12.2%, 11.2%, 6.5%, 6.4%, 6.2%, 5.1%, and 5.0% of the variance respectively (Table 7.4).

Table 7.4: Total variance explained by the components with initial eigenvalue and after rotation

Component	Initial eigenvalue			Rotation sums of squared loadings		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	4.287	19.487	19.487	2.824	12.834	12.834
2	2.550	11.592	31.079	2.676	12.165	24.999
3	1.575	7.161	38.240	2.454	11.154	36.153
4	1.423	6.468	44.707	1.428	6.490	42.643
5	1.280	5.818	50.525	1.409	6.404	49.047
6	1.141	5.186	55.711	1.363	6.198	55.245
7	1.097	4.985	60.696	1.113	5.060	60.305
8	1.004	4.562	***65.258***	1.090	4.953	***65.258***
22	…	…	…	…	…	…

Extraction method: Principal Component Analysis

Table 7.5 presents the rotated factor loadings for twenty two individual indicators. Value loadings below 0.5 are suppressed because they do not represent a strong explanation of the variance (OECD, 2008). It is noted that all twenty two indicators have value loadings above 0.5. All the individual indicators belong to only one principal component, exception of the total land area indicator. However, its loading value is higher in the first component then total land area is disposed in this component. It also can be seen that the first six factors (component) consist of more than one loading value. They explain a total of 55.2% of the variance, with factor one contributing 12.8%, factor two 12.2%, factor three 11.2%, factor four 6.5%, factor five 6.4% and factor six 6.2% of the variance (Table 7.5). Therefore, the interpretation will focus on these six factors.

Factor 1: Economic capacity

Factor 1 is called ***"economic capacity"*** because this factor includes four economic indicators such as income per capita (IPC), saving per capita (SPC), basic asset value (BAV) and total land area (TLA). The IPC indicator has the biggest loading value (0.903), following by the SPC (0.874), the BAV (0.722), and the TLA (0.617). It is noted that the four indicators have positive loadings and relate to household economic capacity. In reality, income and saving has positive relationship normally. It means that high income level generate more savings and vice versa. Money from the saving can be used for many purposes; for example, building houses, and/or buying farming tools, motorbikes, computers, freezers, televisions, and other furniture resulting higher BAV. Many cases in rural areas, farmers enlarge their farms by buying more land from their savings. Therefore, this factor presents how wealthy is a household.

Table 7.5: Rotated component matrix of the factor analysis showing the value loadings above 0.5

Input variables	Component							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
NOH		0.874						
EOS		0.747						
EOT		0.722						
EOD		0.531						
CDR		0.635						
CHR					0.801			
HCR					0.805			
DTI								0.830
CIR			0.774					
DER				0.633				
ILR				0.690				
WIR			-0.522					
IPC	0.903							
SPC	0.874							
NIS						0.860		
HIR							0.848	
BAV	0.722							
NRT						0.633		
NWS			0.672					
TLA	0.617		0.528					
PLA			0.622					
WOC				-0.556				
Variance explained	*12.8%*	*12.2%*	*11.2%*	*6.5%*	*6.4%*	*6.2%*	*5.1%*	*5.0%*
Cumulative variance	*12.8%*	*25.0%*	*36.2%*	*42.6%*	*49.0%*	*55.2%*	*60.3%*	*65.3%*
Factor name	*Economic*	*Hazard*	*Zone*	*Dependency*	*Health*	*Skill*		

Extraction method: Principal Component Analysis; Rotation method: Varimax with Kaiser Normalization

Factor 2: Hazard exposure

The second factor is named ***"hazard exposure"*** because the indicators relate to hazard frequency and severity. There are five indicators belong to this factor including number of hazards (NOH), effects of salinity (EOS), effects of tide (EOT), effects of drought (EOD) and crop damaged ratio (CDR). Their loading values are decreasing as NOH 0.874, EOS 0.747, EOT 0.722, CDR 0.635, and EOD 0.531. As identified in previous chapters, salinity intrusion, tide and drought are the most three important hazards in the study site. More hazards occurred and/or higher severity level will damage more crops. As result, people livelihoods are affected then vulnerability will increase.

Factor 3: Zone

The third factor is called ***"Zone"*** due to the fact that the indicators can be logically linked with ecological zones. It consists of five indicators but one of them (TLA) belongs to the factor 1 because of higher loading value (0.617 in factor 1 compared to 0.528 in factor 3; Table 7.5). Thus, factor 2 includes four indicators as crop income ratio (CIR), wage income ratio (WIR), numbers of water sources (NWS), and protected land area (PLA). As reported in Chapter 6, the study area is divided into 3 ecological zones. Each zone has particular farming systems (i.e. crops or aquaculture), livelihood activities (i.e. wage or agriculture), access to water sources (i.e. brackish or fresh water). Beside, the division of different zones depends strongly on the dyke systems that prevent sea water intrusion. Therefore, the PLA indicator has a close relationship with zone factor. The loading value of TLA indicator is also above 0.5 in this classification due to the fact that various population densities in the three zones (see details in section 7.3.1). In short, the vulnerability level can be different depending on the zone factor.

Factor 4: Dependency

There are three indicators with loading value above 0.5 in the fourth component such as illiteracy rate (ILR with loading value of 0.690), dependency ratio (DER with loading value of 0.633), and working outside of community (WOC with loading value of 0.556). These three indicators are more or less related to ***"dependency"*** issue. Low education or illiteracy people often have less chance to find good income. Households with high ratio of people under 15 and over 65 years of age to the total family members between 15 and

65 years of age means that their labor forces are limited, thus affecting the livelihoods. Working outside of community provides opportunity to earn more income. However in many cases, failures of migration in cities put higher pressures to family because they may return to the home villages with some debts.

Factor 5: Health

The fifth component is identified by two indicators with loading value higher than 0.5 that regarding to ***"health"*** of family members. First, the CHR indicator, ratio of chronically ill people to total number of family members, has loading value of 0.801. Second, the loading value of HCR indicator, ratio of health costs to total income, is 0.805. For both indicators is the higher value is worse thus indicates more vulnerability.

Factor 6: Skill

The sixth factor is named ***"skill"*** because two indicators (NIS – Number of Income Sources and NRT – Numbers of Received Trainings) in this component can be linked with skills of people. The loading value of NIS and NRT indicators are 0.860 and 0.633 respectively. Diversification of income sources is a way to reduce risk on one hand and enhance capacity on the other. In rural areas, the diversification is often regarding to knowledge and skills of farmers. Capacity buildings through extension services are common approach to improve knowledge and skills for them in the Mekong delta (De 2006; Binh, 2008). Thus, farmers who receive more training classes will have better skills to increase agricultural production as well as diversify income sources for their households.

In short, result from the factor analysis showed that even 22 individual indicators belongs to the eight components but they relate to three elements of vulnerability concept. Factor 1 and 6 link to *capacity* as they consist of human skills and economic capacity. Factor 2 represents for *exposure* because it includes five indicators regarding to hazards. Whereas most indicators in factor 3, 4, 5 and 8 connect to *susceptibility* like dependency and health issues. Therefore, these indicators can be used to construct vulnerability index.

7.3.3 Sensitivity analysis

Table 7.5 suggests that the overall vulnerability index to salinity intrusion (VISI) can be built based on either:

- Nine indicators (VISI-9) of the first two components explained 24.4% of total variance
- Thirteen indicators (VISI-13) of three components explained 35.7% of total variance
- Sixteen indicators (VISI-16) of four components explained 42.2% of total variance
- Eighteen indicators (VISI-18) of five components explained 48.7% of total variance
- Twenty indicators (VISI-20) of six components explained 54.9% of total variance
- Or twenty two indicators (VISI-22) of all eight components explained 64.9% of total variance

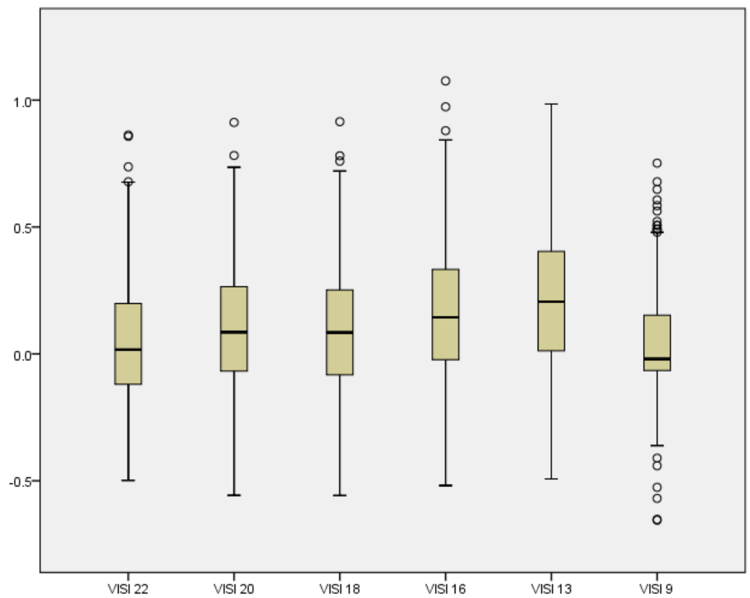


Figure 7.3: Box plots of vulnerability index to salinity intrusion with different combination of indicators

The sensitivity of the VISI was assessed for the above six combinations including 9, 13, 16, 18, 20 and 22 of indicators. Figure 7.3 presents the box plots of each VISI value for the six options. The result shows that more indicators involved in the VISI construction then smaller dispersion are found. It also suggests that the VISI-18, VISI-20 and VISI-22 are more robust than the others. Therefore, the overall vulnerability index should include from 18 to 22 indicators. However, the factor analysis shows that only the first six components has more than one indicators for each factor. These results recommend that the vulnerability index ought to be constructed from 20 indicators of the first six components in the factor analysis. The cumulative variance of these six components are 55.2%. Then, analysis of the VISI in next section will be based on the 20 identified indicators including the NOH, EOS, EOT, EOD, CDR, CHR, HCR, CIR, DER, ILR, WIR, IPC, SPC, NIS, BAV, NRT, NWS, TLA, PLA, and WOC.

7.3.4 Analysis of the vulnerability index

7.3.4.1 Exposure sub-index

Table 7.6 depicted that exposure sub-index (ESI) was not significantly different between ethnic groups because all five exposure indicators like number of hazards (NOH), effects of salinity intrusion (EOS), effects of tide (EOT), effects of drought (EOD), and crop damage ratio (CDR) were the same whether the Kinh or the Khmer ethnicities. However, the ESI value was significantly different amongst ecological zones. Zone 2 received the highest level of hazard exposure (ESI = 0.230) whereas Zone 1 and Zone 3 received the same level of exposure (ESI value in Zone 1 and Zone 3 was 0.092 and 0.112 respectively).

Table 7.6: ANOVA and mean comparisons of exposure indicators and exposure sub-index

	Exposure indicators					ESI
	NOH	EOS	EOT	EOD	CDR	
ANOVA (P-value)						
- Ethnic	0.329	0.680	0.284	0.418	0.598	**0.674**
- Zone	0.000	0.000	0.000	0.763	0.000	**0.000**
- Interaction	0.003	0.002	0.010	0.482	0.402	**0.014**
FACTOR MEANS						
By ethnic						
- Kinh (n = 237)	0.101a	0.189a	0.141a	0.186a	0.091a	**0.142a**
- Khmer (n = 275)	0.113a	0.200a	0.117a	0.208a	0.101a	**0.148a**
By zone						
- Zone 1 (n = 167)	0.071a	0.086a	0.009a	0.201a	0.093b	**0.092a**
- Zone 2 (n = 172)	0.161b	0.381b	0.284c	0.183a	0.142c	**0.230b**
- Zone 3 (n = 173)	0.089a	0.117a	0.094b	0.207a	0.053a	**0.112a**

For mean comparison: indices with the same subscript are not significantly different at the 0.05 level

As described, salinity intrusion in Zone 1 has been controlled thanks to the dyke systems then the indicators of NOH, EOS, EOT in this zone were always better than the others. However, the value of CDR indicator in Zone 1 was still higher than Zone 3 due to the fact that even it is protected by the dykes but crops can be damaged by salinity intrusion, especially in abnormal years (details in Chapter 4 and 5). Beside, farmers in Zone 1 and Zone 2 cultivate rice and sugarcane while in Zone 3 they practice shrimp in the dry season that why the CDR was lowest compared to the others. For drought severity, there was no significance among three zones. It is noted that both Zone 2 and Zone 3 are located outsides of the dykes but the values of NOH, EOS, and EOT in Zone 3 were smaller than Zone 2 because farmers in Zone 3 have been introduced shrimp in the dry season thus salinity intrusion is not perceived as hazard. This confirmed the idea that the same natural phenomenon can impact differently depend on what farming systems are practiced. Therefore, effects of hazards can be reduced by suitable economic activities.

7.3.4.2 Susceptibility sub-index

The indicators of dependency ratio (DER), chronic illness ratio (CHR), and health cost income ratio (HCR) were not significantly different amongst study factors (Table 7.7). The indicator of crop income ratio (CIR) was not significantly different between Kinh and Khmer groups but it happened with ecological zone factor. The value of CIR indicator in Zone 2 was higher than Zone 1 and Zone 3 as 0.396 compared to 0.281 and 0.089 respectively. In Zone 3 farmers practice not only agriculture but also aquaculture. It means that people in Zone 3 has less dependence on crops that is why the indicator of CIR in Zone 3 was smaller than the others. In Zone 2, the CIR was higher than Zone 1 due to the fact that farmers depend much on sugarcane farming while in Zone 1 they can earn from other income sources. The illiteracy rate indicator (ILR) was significantly different amongst ethnic as well as ecological zone factors, and there was an interaction between them (Table 7.7). The Khmer group had higher level of illiteracy than the Kinh one as the values of LIR indicator were 0.212 and 0.110% respectively. Amongst 3 ecological zones, the ILR value was highest in Zone 3 (0.207) whereas Zone 2 it was 0.183 and Zone 3 it was 0.094. For the wage income ratio (WIR), Table 7.7 indicated that the WIR was significantly different between Kinh and Khmer group but not different amongst three zones. The WIR in the Khmer was higher than in the Kinh group. The household survey revealed that sharing of wage income to total income was 38.9% in the Khmer compared to 31.5% in the Kinh population. This result due to the fact that lower education in the Khmer group causes difficulty for them in finding high quality jobs (i.e. teacher, local government staff) then they have to earn from selling their labor in unskilled jobs (also see Chapter 6). Combination of such 6 indicators, the susceptibility sub-index to salinity intrusion (SSI) was calculated. It showed that the Khmer was more susceptible than the Kinh as the values of SSI in these groups was 0.218 and 0.176 respectively (Table 7.7). The SSI was also significantly different amongst 3 zones, the lowest SSI level was situated in Zone 1 (0.187), following Zone 3 (0.188) and Zone 2 (0.216). However, there was not interaction between ethnic groups and zones.

Table 7.7: ANOVA and mean comparisons of susceptibility indicators and susceptibility sub-index

	Susceptibility indicators						SSI
	CHR	HCR	CIR	DER	ILR	WIR	
ANOVA (P-value)							
- Ethnic	0.454	0.136	0.347	0.185	0.000	0.022	**0.000**
- Zone	0.780	0.101	0.000	0.169	0.000	0.067	**0.005**
- Interaction	0.610	0.820	0.000	0.974	0.036	0.198	**0.871**
By ethnic							
- Kinh (n = 237)	0.105a	0.031a	0.243a	0.267a	0.110a	0.300a	**0.176a**
- Khmer (n = 275)	0.117a	0.046a	0.268b	0.294a	0.212b	0.371b	**0.218b**
By zone							
- Zone 1 (n = 167)	0.117a	0.042a	0.281b	0.294a	0.094a	0.294a	**0.187a**
- Zone 2 (n = 172)	0.112a	0.024a	0.396c	0.253a	0.183b	0.331ab	**0.216b**
- Zone 3 (n = 173)	0.104a	0.049a	0.089a	0.295a	0.207b	0.383b	**0.188a**

For mean comparison: indices with the same subscript are not significantly different at the 0.05 level

Various ethnic groups can be affected differently by hazards because they have different levels of capital. In the case of salinity intrusion in the Mekong delta, it found that the SSI in the Khmer group is bigger than in the Kinh group due to many factors but illiteracy rate can be perceived as the most important indicators among 6 ones. From literature, information about illiteracy rate between Khmer and Kinh groups has not been found but it showed that in provinces with higher Khmer population ratio, the literacy rate was lower. For example, the literacy rate for above 15 year old in the rural areas of Mekong delta was about 91.2%. But in Tra Vinh and Soc Trang provinces where the Khmer population was high, accounted for about 30% of total population the literacy rate in the rural areas was only 86.0% in Tra Vinh and 85.8% in Soc Trang (GSO, 2010). In this study, the illiteracy rate in the Khmer group was also higher than in Kinh group as 21.2% compared with 11.0%. Therefore, it is important to focus on educational improvement in Khmer group to reduce its susceptibility to water related hazards in the coastal area of

Mekong delta. In short, less educational level may increase susceptibility level. We found that the educational level was poor in Khmer group and in Zone 2 and Zone 3. Thus, future adaptation strategies should improve education for the people in Zone 2 and Zone 3 in general and for Khmer people in particular.

7.3.4.3 Capacity sub-index

Table 7.8 revealed that six capacity indicators were not differently significant by ethnic groups but they were differently significant among the zones including saving per capita (SPC), number of income sources (NIS), number of water sources (NWS), total land area (TLA), protected land area (PLA), and working outside of community (WOC). Two indicators had the same ANOVA results, significantly different between ethnic groups and amongst ecological zones, but no interaction between 2 analysis factors, they are income per capita (IPC) and basic asset value (BAV). For the last indicator of number of received training (NRT), it is significantly different between the Kinh and Khmer but not for the zones.

Table 7.8: ANOVA and mean comparisons of capacity indicators and adaptive sub-index

	Capacity indicators									**CSI**
	IPC	SPC	NIS	BAV	NRT	NWS	TLA	PLA	WOC	
ANOVA										
- Ethnic	0.002	0.133	0.980	0.001	0.008	0.288	0.648	0.115	0.067	**0.165**
- Zone	0.006	0.004	0.006	0.017	0.959	0.000	0.000	0.000	0.021	**0.000**
- Interaction	0.373	0.369	0.016	0.632	0.026	0.000	0.000	0.000	0.835	**0.000**
FACTOR MEANS										
By ethnic										
- Kinh	0.163b	0.082a	0.312a	0.124b	0.067a	0.355a	0.112a	0.632a	0.361a	**0.245a**
- Khmer	0.126a	0.062a	0.312a	0.093a	0.112b	0.375a	0.118a	0.576a	0.311a	**0.232a**
By zone										
- Zone 1	0.152b	0.071ab	0.288a	0.133b	0.087a	0.413b	0.154c	0.973c	0.345ab	**0.291c**
- Zone 2	0.164b	0.095b	0.296a	0.100a	0.091a	0.392b	0.112b	0.521b	0.286a	**0.228b**
- Zone 3	0.119a	0.047a	0.352b	0.093a	0.093a	0.290a	0.080a	0.317a	0.376b	**0.196a**

For mean comparison: indices with the same subscript are not significantly different at the 0.05 level

Combination of nine individual indicators belongs to capacity aspect; the CSI was not significantly different between two ethnic groups but significantly different amongst three ecological zones and there was interaction between these two factors. The highest value of CSI was in Zone 1 (0.291), following by Zone 2 (0.228) and Zone 3 (0.196). This result expresses the level of capacity in Zone 3 is always lower than the others. There are many reasons which make the CSI in Zone 3 was the worst. Table 7.7 reveals that all four indicators of economic capacity in the first component from factor analysis (see section 7.3.2) such as IPC, SPC, BAV and TLA in Zone 3 received the lowest value compared to Zone 2 and Zone 1. Indeed, the income per capita in Zone 3 was lowest, 7.4 million VND compared with 9.8 in Zone 1 and 10.7 in Zone 2. The saving per capita in Zone 3 was also lower than the others; on average, saving per capita was 2.0 million VND, 3.8 million VND and 0.3 million VND in Zone 1, 2, and 3 respectively (result from the household survey). As mentioned, Zone 2 was dominated by sugarcane and affected by salinity intrusion every year then their economic capital was impacted. However, it is noted that the IPC and SPC in Zone 2 was higher than the other zones in this study because sugarcane price in the surveyed year grew up suddenly. Like IPC and SPC indicators, the indicator of BAV in Zone 3 was also low as 47.8 million VND in Zone 3 compared with 69.5 in Zone 1 and 53.1 in Zone 2. For the TLA indicator, the household survey showed that on average total land area was lowest in Zone 3 (0.44 ha per household) compared with Zone 2 (0.61 ha) and Zone 1 (0.86 ha). In addition, Zone 3 is located fully outside of the dyke systems then its capacity to prevent sea water intrusion is limited. It is necessary to mention that the CSI was not significantly different between ethnic groups but the value of IPC and BAV indicators in Khmer group was lower than Kinh group. In short, Zone 3 has the least adaptive capacity compared with Zone 2 and Zone 1. Therefore, the government should pay more attention to improve capacity for people in Zone 3.

7.3.4.4 Total vulnerability index

Total vulnerability index to salinity intrusion (VISI) with 20 indicators is presented in Table 7.9 that was constructed based on three sub-indices of exposure, susceptibility and capacity elements. The results showed that the VISI was affected significantly by ethnic groups and ecological zones but there was no interaction between these two factors. It means that whether in Zone 1, Zone 2 or Zone 3, the Khmer was more vulnerable than the Kinh group; and whether Kinh or Khmer, vulnerability level was highest in Zone 2, lowest in Zone 1 and middle in Zone 3 (Figure 7.4).

Table 7.9: ANOVA and mean comparisons of sub-indices and total index

	ESI	SSI	CSI	VISI
ANOVA (P-value)				
- Ethnic	0.674	0.000	0.165	**0.000**
- Zone	0.000	0.005	0.000	**0.001**
- Interaction	0.014	0.871	0.000	**0.910**
FACTOR MEANS				
By ethnic				
- Kinh (n = 237)	0.142a	0.176a	0.245a	**0.073a**
- Khmer (n = 275)	0.148a	0.218b	0.232a	**0.134b**
By zone				
- Zone 1 (n = 167)	0.092a	0.187a	0.291c	**-0.011a**
- Zone 2 (n = 172)	0.230b	0.216b	0.228b	**0.218c**
- Zone 3 (n = 173)	0.112a	0.188a	0.196b	**0.103b**

For mean comparison: indices with the same subscript are not significantly different at the 0.05 level

Even the ESI and CSI was not different between Kinh and Khmer group but the SSI was different that results in higher total vulnerability in Khmer population. Therefore, the key issues regarding to risk reduction purpose in the study areas are improvement of capacity for the Khmer group focusing on susceptibility dimension. Of which, education policy can be considered as important because higher education level will improve income per capita and reduce susceptibility. In recent years, the government has many supporting programs in Khmer communities to improve education but they are still not strong enough because of top-down approach. Then, future policy should take into account the local conditions.

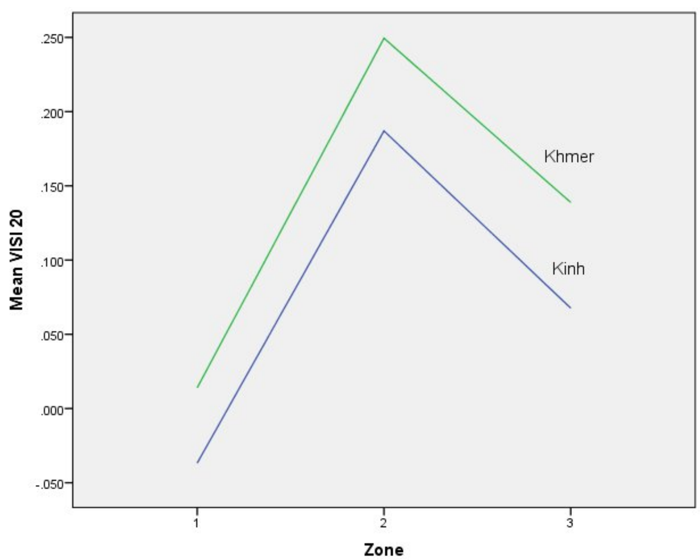


Figure 7.4: Comparison of total vulnerability among different ecological zones and ethnic groups

Different zones are associated with different levels of vulnerability. Main reasons regarding this difference are irrigation infrastructure investment and current economic activities. Zone 1 received a lot of benefits from dyke systems to prevent salinity intrusion. Thanks to this intervention, farmers can grow 2 or 3 rice crops per year thus they have opportunities to improve economic situation on one hand and access to health and educational services on the other hand. Zone 3 is located outsides of the dykes like Zone 2 but it has integrated rice – shrimp farming systems. This practice can reduce risk to salinity because shrimp grow under brackish water environment. Even the rice-shrimp integration showed many advantages in term of environmental risk reduction but it often faces with shrimp diseases and unstable market price (detail in Chapter 6). While in Zone 2, farmers mainly rely on sugarcane farming which is strongly impacted by saline water. Consequently, its vulnerability was highest. Therefore, it is necessary to build up better adaptation measures for this zone.

7.4 Conclusion

This study revealed that vulnerability to salinity intrusion is affected depending on the complex socio-ecological systems. Through vulnerability index approach the most vulnerable region and ethnicity as well as dimension of vulnerability are identified that plays very important role to develop further adaptation policies. Another advantage of this approach is a combination of many individual indicators into a single index that reflects the realistic context. For example, if people rely on income per capita to assess vulnerability then it will conclude that Zone 2 is the less vulnerable to salinity intrusion, but it does not reflect the reality because the market price of dominant crop such as sugarcane in this zone grew up suddenly in the surveyed year. One of disadvantages of index approach is indicator selection. Lessons learned from this study showed that it is necessary to combine secondary information through literature review and primary data source via participatory vulnerability analysis. Then, the index will reveal the nature of the phenomenon. In short, composite indicator approach should be applied to measure vulnerability in different socio-ecological contexts.

Chapter 8: CONCLUSIONS AND RECOMMENDATIONS

8.1 Major findings

Analysis of salinity concentration in the period of 1995-2011 confirmed that salinity intrusion in the coastal areas of Mekong delta depends on many weather factors and the hydrological regimes such as air temperature, evaporation, rainfall, upstream flow and tidal movement from the sea. Therefore, it changes year-by-year and fluctuates over time without any regular patterns. However, the findings proves that this hazard tends to increase during the research period (1995-2011). Salinity intrusion starts earlier in the year, intrudes further inlands and remains longer in the river and canal networks in the dry season. In abnormal (dry) years, crops are destroyed heavily resulting in degradation of local people livelihoods.

To cope with and to adapt to salinity intrusion both formal and informal adaptation measures have been developed and implemented; for example, dyke buildings, crop calendar adjustments, farming system changes, ground water exploitation, etc. They have shown many positive results for agricultural and economic development as farmers can grow two or even three rice crops per year. However, current adaptation options have shown some limitations because they do not fully consider the difference and interaction socio-ecological systems in the coastal areas. These sometimes lead to conflicts or generate harmful consequences to the systems (i.e. declining natural fish resources, conflicting between freshwater users for crops and brackish water users for aquaculture, increasing water level outside the dykes during closed gate period, etc.). In addition, most of these measures proposed or currently in place do not consider sea level rise and upstream flow change in the long-term.

There are differences in vulnerability to salinity intrusion depending on socio-ecological systems in the study areas. In freshwater control regions, sea water intrusion is prevented but the crops are always being at risk due to freshwater shortage or leakage problem, especially in the dry years. In the other side of the dykes, people are more vulnerable to salinity issue because crops can not be grown during salinity period. Moreover, these areas are strongly affected by tidal influence, floods become more serious, particularly when the sluice gates are closed to protect agricultural production. The study found that causes of vulnerability depend not only on natural conditions but also socio-economic drivers such as poverty rate, educational level, technological prowess, access to land, access to market, market prices, crop diseases, farming system practices, job opportunities, etc. Using household survey data to construct vulnerability index to salinity intrusion (VISI) it was found that the Khmer people are more vulnerable than the Kinh in all three ecological zones because they have less adaptive capacities. This is very important to develop suitable policies for the most vulnerable ethnicity and communities to enhance their resilience.

8.2 Reflection on current literatures

8.2.1 Multiple dimensions of vulnerability to slow-onset hazard

As indicated in previous chapters, current knowledge is not enough to address slow-onset hazards requiring more works to enhance our understanding of vulnerability to creeping events. By assessing vulnerability to salinity intrusion in the Mekong delta of Vietnam, this study provides more information and facts to be aware of slow-onset hazards. The results show that vulnerability to slow-onset hazards is influenced by multiple dimensions that can be group into three spheres such as social, economic and environmental (Figure 8.1).

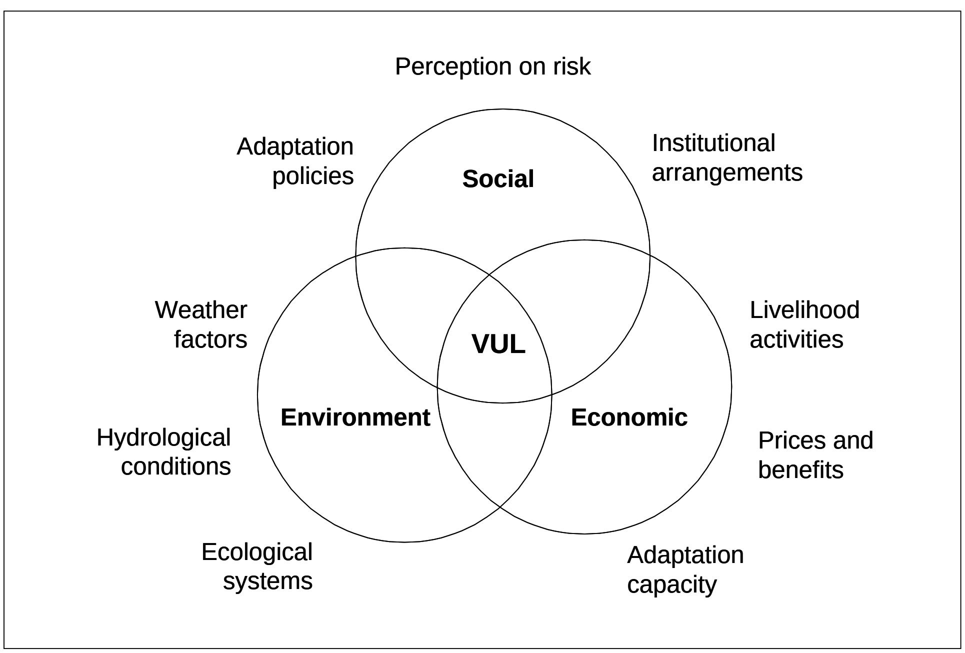


Figure 8.1 Multiple dimensions influenced vulnerability (VUL) to slow-onset hazards

Many social factors can influence vulnerability to both sudden-onset and slow-onset hazards. Beside common factors, it is recognized that perception of risk, adaptation policies, and institutional arrangements should take into account when carrying out vulnerability assessment to slow-onset hazards. Our study shows that salinity intrusion is increasing slowly in the coastal areas of the Mekong delta but local people have not recognized it or they perceived as it was within normal variability. Then, farmers continue to expand and intensify their crops, local governments also believe in their current adaptation policies and institutional arrangements. However, in 2011 the crops were heavily destroyed because salinity level increased beyond the normal range. Therefore, it is necessary to consider trends and other factors and develop different approach to manage the slow-onset hazards more efficiently.

Vulnerability to slow-onset hazards is also influenced by livelihood activities, adaptation capacity, and market prices of agricultural products. In this study, it was found that even at the same level of exposure to salinity intrusion but there were different levels of vulnerability depending on various farming systems and the adaptation capacity of different groups. Besides, increase of market prices of agricultural products tempt farmers to grow more crops even in high risk areas causing more damage when salinity level overwhelms crop resistance. These are important features of slow-onset events because in the early stage of hazards different groups may have different livelihood strategies then different capacities to adapt when the events occur.

Results also indicate that slow-onset hazard such as salinity intrusion is strongly affected by environmental factors like rainfall, temperature, hydrological conditions and state of the ecological systems. It is noted that vulnerability assessment should take into account these factors not only at local but also at regional scale because there is a relationship between different social-ecological systems (i.e. salinity intrusion in the Mekong delta may be affected by hydropower development upstream in the river basin).

In short, vulnerability to slow-onset hazards has multiple dimensions and many of them have long developmental process. Under the ongoing social, economic and environmental changes the vulnerability level may continue to increase in the future. Therefore, assessment of vulnerability to slow-onset hazards should consider different aspects of vulnerability (Figure 8.1), not only at current stage but also past and future trends.

8.2.2 Hazard development stages and vulnerability

Current approach to disaster management includes 3 main stages such as preparedness, response and recovery. Depending on type of hazard, social-ecological conditions, and policies the recovery period can be short or long, but after this period vulnerability level should be the same as before the event occurs like visualized in Figure 8.2. This approach can be applied not only for sudden-onset hazards but also for slow-onset hazards. However, it is argued that for the slow-onset hazards it is necessary to develop an other approach. Because these hazards are growing very slowly within a long process; therefore, if people employ the old approach vulnerability level will be widen as following discussion.

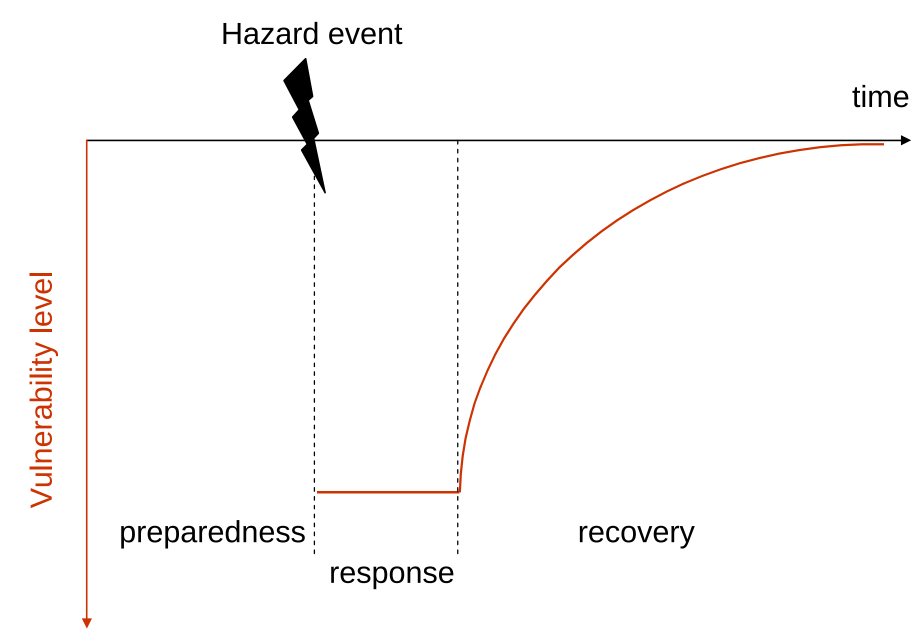


Figure 8.2 Three stages of sudden-onset hazard and their vulnerability level

(Based on Bogardi, 2006 in Fekete, 2010)

Due to its creeping nature, the development process of slow-onset hazards can be divided into three stages as early, transitional and acute (Figure 8.3). In the early stage, the hazard severity is below a threshold thus the social-ecological system can function normally. Then vulnerability is low as V0. Later in the transitional stage, the hazard severity level transgresses the threshold level a few times and that can cause harm to the system: For example, in this the study salinity level in the rice fields in some years like 2004, 2005 and 2011 exceeded the threshold of 4 g/l and destroyed a lot of crops (Chapter 5). As visualized in Figure 8.3 the hazard (above threshold) happens two times during the transitional period. When the hazard occurs at the first time, the system is vulnerable at V1 level. After this event, the vulnerability is reduced thank to response and recovery process. However, it has not yet fully recovered when the second hazard occurs and increases vulnerability as indicated at V2. The severity level continues to increase and at a certain time it always above the threshold; it results that the entire system will be subject to collapse but there is no response and recovery abilities hence vulnerability will be very high in the acute stage (V3). Therefore, if people do not have right policies to intervene at early stage the system will be not function very well in later ones, then vulnerability to slow-onset hazards are even higher than sudden-onset hazards in long term development.

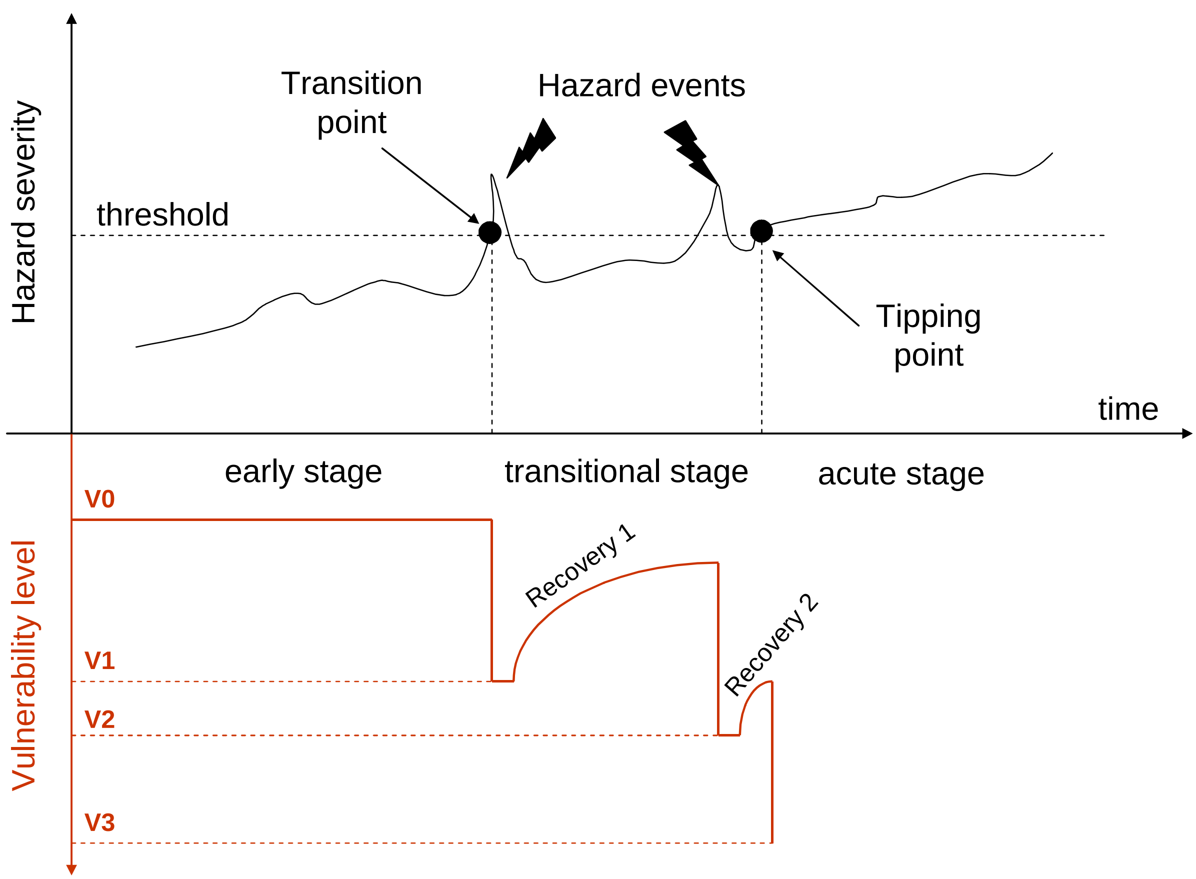


Figure 8.3 Three stages of slow-onset hazard and their vulnerability levels

8.2.3 Framework to assess slow-onset hazard vulnerability

The BBC conceptual framework used in this vulnerability assessment takes into account 3 pillars of sustainable development such as social, economic and environmental dimensions; however, it does not show a relationship between these three factors in a certain system with current and past vulnerabilities causing by hazards, especially the cases of slow-onset events which creep slowly over time. Current literature review also identified that the slow-onset hazards are not yet conceptually well defined (Guppy and Twigg, 2013). Then, it is necessary to develop conceptual framework to assess vulnerability to slow-onset hazards.

Figure 8.4 suggests a **v**ulnerability **a**ssessment **f**ramework for **slo**w-onset hazard (VAFSLO). This VAFSLO conceptual framework shows that current vulnerability is caused not only by present slow-onset event (over the threshold, see more in Figure 8.3) but also by social, economic and environmental conditions as well as result of adaptation policies from the previous period. The adaptation policies themselves are also shaped by the social-ecological system where the hazard occurs.

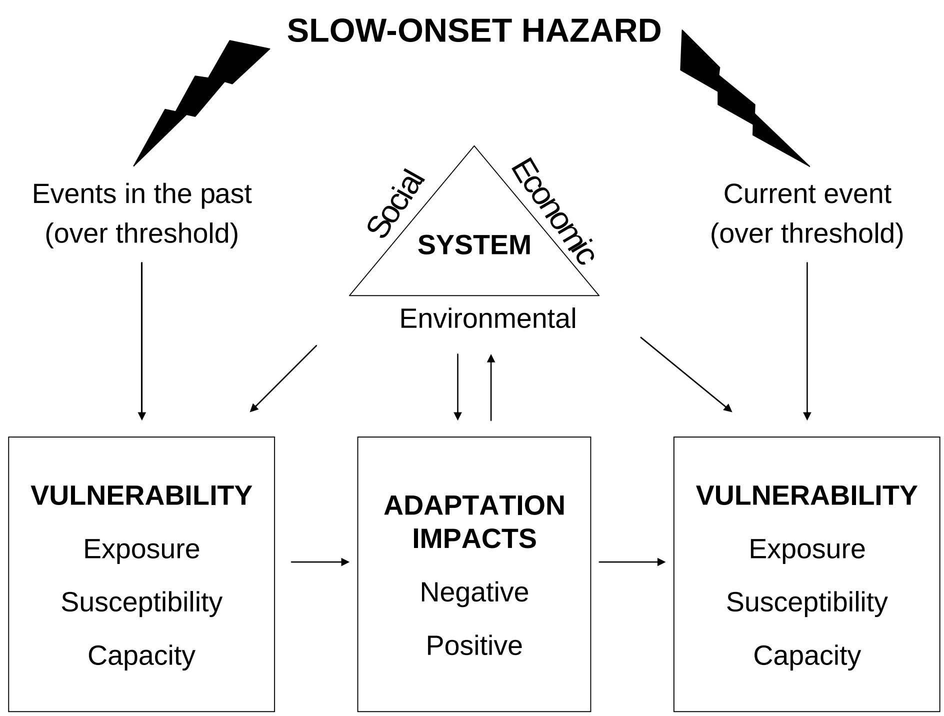


Figure 8.4: The VAFSLO framework for slow-onset hazard vulnerability assessment

After that, the system will be changing due to such interventions. Most adaptations have two sides of negative and positive. The negative impacts contribute to exposure and susceptibility elements while positive impacts increase adaptive capacity. Overall, vulnerability assessment to slow-onset hazard should look back what happened in the past and bring them into current analysis to understand entire process rather than considering single event like sudden-onset hazard (see an example in Box 8.1).

Box 8.1: Building the VAFSLO framework from the case study in Mekong delta

The VAFSLO conceptual framework is drawn from our vulnerability assessment to salinity intrusion in the Mekong delta in 2011. Salinity concentration happened in the past caused heavy damage and loss; for example, in 1998, 2004 and 2005. After that, local people and government developed many adaptation strategies to control salinity intrusion, importantly dyke buildings. Dykes were constructed strongly depend on social-ecological systems (i.e. capital investment capacity, existing infrastructure and farming systems, etc). The dyke policy brings a lot of benefits for socio-economic development as farmers can grow more crops. However, it also causes many negative impacts and potentially increases risk to crops even in freshwater control area. This is recorded by high level of vulnerability to salinity intrusion in 2011. As analyzed in Chapter 5, serious crop damages in 2011 result from different reasons, not only by hazard severity itself but also by other factors such as people perception of risk, dyke condition, sluice gate operation, localities, etc which happen before the event.

(Draw from own survey – see also Chapter 5)

8.2.4 Approach to manage slow-onset hazards

Up to date, people use the sudden-onset hazard management approach for slow-onset hazards because they focus only on a “single” hazard event rather than the whole process of creeping hazards. For example, salinity intrusion in this study is only considered as disaster in 1998, 2004, 2005, and 2011 due to the fact that the salinity level exceeded the threshold causing heavy damages to crops. In such years, farmers and local governments had many activities and policies to response and recover after the hazard (details in Chapter 5 and 6). By this approach, people perceive salinity intrusion as sudden-onset hazard and react in short term. However, salinity intrusion tends to increase in long term then the above approach is less efficient requiring new approach for slow-onset hazard management.

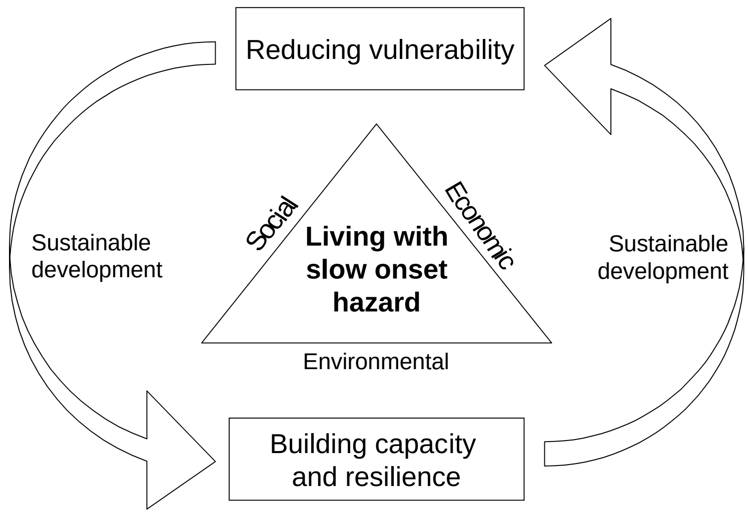


Figure 8.5 The LIWISLO approach to manage slow-onset hazard

In this context, "**li**ving **wi**th **slo**w-onset hazard" (LIWISLO) approach described as Figure 8.5 may deal with such challenge. The LIWISLO concept emphasizes that people develop adaptation policies based on existing social-ecological system within which they live rather than changing it. Two main focuses in this approach include vulnerability reduction and capacity building which influence each other. Vulnerability can be reduced by addressing its multiple dimensions of social, economic and environmental drivers (i.e. diversification of livelihoods, reforestations, effective institutional arrangement, etc). This in turn helps to enhance adaptive capacity and resilience of households and communities living under slow-onset process. Then, higher capacity and resilience will provide more resources to reduce vulnerability. The LIWISLO approach benefits in many ways such as (case study in Box 8.2):

- Conservation and restoration of ecosystems, biodiversity
- Cultural protection, conflict reduction, use of local knowledge and experiences,
- Risk reduction not only for slow-onset hazards themselves but also for other stressors due to capacity building process
- Sustainable socio-economic development in long term
- Cost saving (i.e. building dykes to control salinity intrusion)
- Can be associated with other tools and approaches (i.e. integrated water resource management – IWRM, integrated coastal zone management – ICZM)

Box 8.2: Advantages of the LIWISLO approach – the case of salinity intrusion in the Mekong delta

There are two main approaches to manage salinity intrusion in the Mekong delta: building dykes to prevent salinity intrusion for rice intensification and "living with salinity intrusion". In later approach, people do not build dykes to control saline water but they develop their livelihoods based on natural ecosystems; for example, integrated rice-shrimp farming systems where rice is cultivated in the wet season and shrimp is raised in the dry season when saline water comes. This approach shows many benefits such as: no cost for building dykes, biodiversity conservation generating abundant natural fish resources, social equity due to the fact that resource poor farmers can rely on natural ecosystems, no conflict between different sides of dykes, less chemical use compared to rice intensification, sustainable land and water management, risk reduction due to diversification of income sources and no dependence on freshwater in the dry season, use of traditional knowledge and experiences, and cultural protection.

(Draw from own survey)

In short, it is important to pay more attention on slow-onset hazards even in the early stage where vulnerability is still low and damage may not occur at all. Moreover, adaptation strategies should take into account the multiple dimensions of slow-onset hazard in long term development rather than addressing single hazard event in short period. In this context, the LIWISLO approach should be employed to reduce vulnerability on one hand and build capacity on the other.

8.2.5 Advantages of mixed method to assess vulnerability

Our method to assess vulnerability differs from previous studies in that it combines qualitative and quantitative tools and uses primary data from household survey to construct vulnerability index (Figure 8.6). The advantages of the mixed method include:

- Different data sources and methods will complement each other and reduce bias
- From the PVA survey potential indicators are identified at local context which are difficult to obtain by other approach
- By using primary data the mixed method covers all aspects of vulnerability in reality that can not be done with secondary data
- By using household data, it provides empirical social vulnerability to salinity hazard that is not achieved by climate models

- By mixed method, the most vulnerable groups (i.e. the poor, the Khmer people) as well as roots of vulnerability in different ecological zones are identified.
- This also provides practical tool for policy makers and related stakeholders in the regions to assess vulnerability and adaptation projects or programs

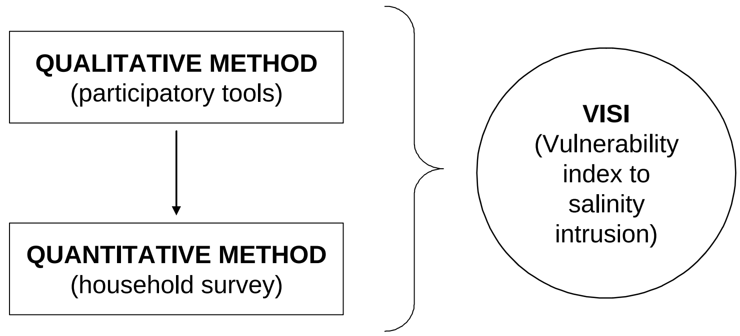


Figure 8.6 Mixed method to measure vulnerability to salinity intrusion in the Mekong delta

8.3 Recommendations for local authorities

There are many useful recommendations that can be developed for local authority based on this study results in order to have better policies to address slow-onset hazard such as salinity intrusion in the coastal areas of Mekong delta. The LIWISLO approach can be applied in this context considering multiple dimensions of vulnerability to reduce it on one hand and build resilience for long term development on the other hand.

About resources use and management: Under the contexts of sea level rise and climate change, saline water should be considered as useful resources rather than constrains because it can bring big amount of natural fish production and be suitable for aquaculture which has been developed so far. By this "living with salinity" approach, risks can be reduced through diversification of products and income sources. Therefore, the concept of LIWISLO together with IWRM and ICZM should be tested and applied in the research areas.

About irrigation and production planning: Current irrigation infrastructures should be upgraded to reduce leakage problem and to maintain their roles under sea level rise in long term period. At the same time, it is necessary to develop "soft measures" (i.e. new varieties, modern technologies, seasonal calendar adjustment, suitable farming systems, etc.) for each ecological zone based on water resources availability. Then proper agricultural production systems should be planned for specific context in the coastal regions.

About coordination between related stakeholders: There are needs of collaboration and coordination between related stakeholders such as Department of Agriculture and Rural Development, Department of Irrigation, Center of Hydrometeorology in terms of data sharing and communication in order to have better sluice gate operation plan as well as seasonal calendar for farmers to reduce vulnerability to salinity problem.

About adaptation approach: Adaptation measures to climate change in general and salinity intrusion in particular should be developed based on community needs and capacities. These adaptation policies should be considered not only economic factors but also ecological environment and differences in vulnerability among social groups, especially the most vulnerable such as low income group, Khmer people, and communities living outside of dykes. The PVA approach which has been employed in this study showed many advantages. Through PVA process, the most vulnerable groups will be identified and their needs as well as capacities are also assessed. Therefore, it should be used to build up future adaptation policies.

About composite indicators: The VISI is constructed in this study helps to summarize multiple dimensional phenomenon as vulnerability concept into a simple index which is useful tool to support decision makers. Then, this technique should be applied in order to measure vulnerability to other hazards as well and assess respective adaptation policies in the future.

In short, instead of prevent sea water intrusion by focusing on hard measures as dyke development nowadays, the local authority should consider sea water as resources and make use of it through combination of soft and hard adaptation policies. By this approach, ecosystem is conserved, conflict and vulnerability will reduce whereas resilience and capacity will increase.

8.4 Challenges and outlook

The VAFSLO framework and LIWISLO approach are useful tools to address slow-onset hazards for sustainable development in long term. However, there still remain many challenges. *First*, the VAFSLO conceptual framework emphasizes different dimensions of vulnerability but do not provide potential indicators to measure. Then people must develop their own indicators when they apply the framework in a specific context. *Second*, the VAFSLO framework stresses the integration of different stages of slow-onset events. However, it is not easy to answer where is the threshold level and how to define each stage during a creeping process due to the fact that vulnerability to slow-onset hazards varies with different social-ecological systems. For example, in crop production system threshold of salinity may be defined at 4 g/l because most crops can not survive above such level, but it can be higher in tiger shrimp farms. In other word, determination of transition and tipping points in Figure 8.3 is still a challenge requiring more filed research at local level. *Third*, certain adaptation policy may have negative impacts that prevent vulnerability reduction and capacity building hampering sustainable development strategy in LIWISLO approach. *Fourth*, vulnerability is shaped by multiple dimensions which influence among each other (i.e. interaction between social and ecological factors), change over time or dynamic system (i.e. socio-economic development), nonlinearity (i.e. salinity level tends to increase without any regulation) and high uncertainty (i.e. weather factors, climate change, interventions like hydropower plants or irrigation development from upstream influence downstream); hence, it is difficult to capture these characteristics of vulnerability to slow-onset hazards. *Last but not least*, management of slow-onset hazards requires an active participation of related stakeholders including community level, even minority ethnics (i.e. Khmer people in Vietnam); however, coordination and collaboration are weak then better institutional arrangement to motivate people is important to apply LIWISLO approach.

In summary, this study provides more knowledge to improve our understandings on slow-onset hazards in general and salinity intrusion in particular which receive less attention previously. Through the study, VAFSLO framework and LIWISLO approach are developed which can be used for vulnerability assessment and management of slow-onset hazards, especially under climate change and sea level rise contexts nowadays. Further research and application of such above framework and approach are needed in local hazard condition. In other word, the two frameworks should be tested, how they would have brought less suffering from sea water intrusion.

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Documentation of Academic History

Qualifications

Year	*Academic institution*	*Subject*	*Degree*
2009-2015	Boon University and United Nations University	Vulnerability assessment	PhD
2006-2008	Joint academic degree from Ghent University, Agrocampus Rennes, Humboldt University of Berlin and University of Cordoba	Rural Development	Master
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Working experiences

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2000-2015	Mekong Delta Development Research Institute, Can Tho University, Vietnam	Researcher and Lecturer

Research interest and experiences

- Agricultural extension
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- Vulnerability and adaptation to climate change

List of Publications and Presentations Related to PhD

Binh, N. T. (2010). Vulnerability and Adaptation to Salinity Intrusion in the Coastal Province of Tra Vinh, Vietnam. In: Setiadi N., Birkmann J., and Buckle P. (Eds) Disaster Risk Reduction and Climate Change Adaptation: Case Studies from South and Southeast Asia. SOURCE Publication Series of United Nations University, Institute for Environment and Human Security, No. 14/2010, 32-39pp.

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Vulnerability and Adaptation to Salinity Intrusion in the Mekong Delta of Vietnam

by Nguyen Thanh Binh

Vulnerability conceptualizations and assessments for natural hazards are not new, but further research is still needed, particularly regarding slow-onset hazards. Slow-onset hazards tend to receive less attention due to their gradual development which often goes unnoticed in the early phases. However, at a certain stage, a combination of stresses may exceed the coping capacity of vulnerable socio-ecological systems, raising the risk that the entire system may collapse due to the lack of a timely response. Hence the losses from creeping processes may be even more substantial than in the case of sudden-onset hazards. As such, there is a clear need to respond to slow-onset hazards with more appropriate actions in the early phases in order to avoid damage to livelihoods before they reach an acute phase.

Salinity intrusion is considered a slow-onset hazard and is particularly important in low-lying areas such as the Vietnamese Mekong delta where the economy is dominated by the agricultural sector. In this regard, it is necessary to analyze salinity data trends to have better understanding of past and present changes in the hazard and to assess the impacts of this on agriculture and livelihoods with a consideration of adaptation strategies to salinity intrusion in different socio-ecological settings in the delta.

The study developed and applied the VAFSLO framework (Vulnerability Assessment Framework for Slow-onset hazards) and LIWISLO approach (Living With Slow-onset hazards) to assess the vulnerability and management of slow-onset hazards, especially under climate change and sea level rise contexts.

The research was conducted within the WISDOM project, a German-Vietnamese Initiative to develop a Water-related Information System for the Sustainable Development of the Vietnamese Mekong Delta.

Nguyen Thanh Binh earned his PhD in Agricultural Sciences at the University of Bonn, Germany, while conducting his research within the structure of the UNU-EHS.

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