VULNERABILITY AND ADAPTATION ASSESSMENT OF THE SHRIMP FARMING TO EXTREME FLOODS EVENTS : A CASE STUDY OF THE BANGPAKONG SUB-BASIN, BANGPAKONG RIVER BASIN IN CHACHOENGSAO PROVINCE

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การประเมินความอ่อนไหวและการปรับตัวของฟาร์มเพาะเลี้ยงกุ้งทะเลต่อสถานการณ์น้ำท่วมฉับพลัน : กรณีศึกษาที่ราบแม่น้ำบางปะกง ลุ่มน้ำบางปะกง จังหวัดฉะเชิงเทรา

นายชัยพร สีขาว

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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ชัยพร สีขาว : การประเมินความอ่อนไหวและการปรับตัวของฟาร์มเพาะเลี้ยงกุ้งทะเลต่อสถานการณ์น้ำท่วมฉับพลัน : กรณีศึกษาที่ราบแม่น้ำบางปะกง ลุ่มน้ำบางปะกง จังหวัดฉะเชิงเทรา (VULNERABILITY AND ADAPTATION ASSESSMENT OF THE SHRIMP FARMINGTO EXTREME FLOODS EVENTS : A CASE STUDY OF THE BANGPAKONG SUB-BASIN, BANGPAKONG RIVER BASIN IN CHACHOENGSAO PROVINCE) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร. ชนาธิป ผาริโน, 188 หน้า.

ภัยพิบัติน้ำจากท่วมซึ่งเป็นผลจากพายุโซนร้อนได้ก่อให้เกิดความเสียหายอย่างกว้างขาวและต่อเนื่องต่อฟาร์มเพาะเลี้ยงกุ้งในลุ่มน้ำแม่น้ำบางปะกง จังหวัดฉะเชิงเทรา ประเทศไทย ซึ่งพื้นที่ดังกล่าวเป็นพื้นที่ที่มีพื้นที่เพาะเลี้ยงกุ้งใหญ่ที่สุดในประเทศ จังหวัดฉะเชิงเทรายังเป็นแหล่งที่ผลิตกุ้งที่สำคัญสำหรับบริโภคภายในประเทศและส่งออกยังต่างประเทศ แต่จังหวัดฉะเชิงเทรากลับประสบปัญหาน้ำท่วมบ่อยครั้ง ดังนั้น วิทยานิพนธ์ฉบับนี้จึงมีวัตถุประสงค์เพื่อประเมินพื้นที่เพาะเลี้ยงกุ้งที่มีความอ่อนไหวต่อน้ำท่วม และแนะนำทางเลือกในการปรับตัวที่ศึกษาจากเหตุการณ์น้ำท่วมที่ผ่านมาเพื่อนำมาใช้ในการรับมือกับน้ำท่วมต่อไป นอกจากนี้ วัตถุประสงค์ของการศึกษานี้ยังครอบคลุมถึงปัจจัยหลักที่มีผลต่อต่อความสามารถในการปรับตัวของผู้เพาะเลี้ยงกุ้งในประเทศไทยและการศึกษาต้นทุน-ผลตอบแทนของทางเลือกในการปรับตัวต่างๆ

การศึกษานี้ได้พัฒนาแผนที่ความอ่อนไหวต่อน้ำท่วมจากธรณีสิ่งแวดล้อมของพื้นที่ศึกษา ซึ่งแผนที่ดังกล่าวได้จัดทำผ่านระบบสารสนเทศภูมิศาสตร์ (GIS) และการประเมินแบบหลายหลักเกณฑ์ แผนที่ความอ่อนไหวทั้งในปัจจุบันและอนาคตแสดงให้เห็นว่าพื้นที่ฟาร์มเลี้ยงกุ้งในลุ่มน้ำแม่น้ำบางปะกงเป็นพื้นที่ที่เปราะบางต่อการถูกน้ำท่วมเมื่อมีปริมาณน้ำฝนสะสมใน 10 วันมากกว่า 250-300 มิลลิเมตร ซึ่งจากแผนที่ความเปราะบางที่ได้จากแบบจำลองนี้สอดคล้องกับพื้นที่จริงที่ได้รับผลกระทบจากน้ำท่วมเมื่อปี 2554 สำหรับการศึกษาปัจจัยหลักที่มีผลต่อความสามารถในการปรับตัวได้ศึกษาโดยการใช้แบบสอบถามและการสัมภาษณ์เชิงลึกกับผู้เพาะเลี้ยงกุ้งประมาณ 100 รายที่เคยได้รับผลกระทบจากเหตุการณ์น้ำท่วมที่ผ่านมา ซึ่งการสำรวจนี้จะช่วยให้สามารถแบ่งระดับของปัจจัยที่มีผลต่อการปรับตัวได้ ผลการสำรวจพบว่า 5 ปัจจัยที่เกี่ยวข้องกับเศรษฐกิจ-สังคม เช่น ระดับการศึกษา ประสบการณ์ในการเลี้ยงกุ้ง กลุ่มรายได้ ขนาดฟาร์มเลี้ยง และอาชีพเสริม เป็นปัจจัยที่มีผลต่อการตัดสินใจในการปรับตัว นอกจากนั้น การศึกษานี้ยังได้จัดทำแผนที่เสี่ยงต่อน้ำท่วมที่พิจารณารวมกันระหว่างความน่าจะเป็นต่อการเกิดน้ำท่วมกับแผนที่ความเปราะบางที่ได้จากการศึกษาสภาพภูมิประเทศและเศรษฐกิจ-สังคมของผู้เพาะเลี้ยงกุ้งทะเล เพื่อนำผลที่ได้มาวิเคราะห์หามาตรการที่สามารถนำมาใช้ในการลดความเสี่ยงจากน้ำท่วมโดยการเปรียบเทียบระหว่างกำไรสุทธิและต้นทุนจากทางเลือกต่างๆ รวมถึงการหาค่าความเสียหายทั้งหมดหากไม่มีการดำเนินการใดๆ ในการนำมาใช้ลดผลกระทบจากน้ำท่วม ซึ่งในการดำเนินการวิเคราะห์ดังกล่าว พบว่า สองในสามของพื้นที่เลี้ยงกุ้งทั้งหมดในจังหวัดฉะเชิงเทรามีความเสี่ยงต่อการถูกน้ำท่วมหากมีปริมาณน้ำฝนสะสมที่มากกว่า 250 มิลลิเมตรในระยะเวลา 10 วัน แต่หากมีการเพิ่มความสูงของคันดินให้เพียงพอก็สามารถลดความเสี่ยงน้ำท่วมและให้ผลตอบแทนจากการขายกุ้งกลับได้มากที่สุดเมื่อเทียบกับทางเลือกอื่นๆ แต่ทางเลือกนี้จะเหมาะสมกับพื้นที่ที่มีความเสี่ยงที่จะถูกน้ำท่วมในทุกๆ 2 ปี สำหรับมาตรการที่ไม่จำเป็นต้องก่อสร้างใดๆ เช่น การจับกุ้งก่อนน้ำท่วม หรือการเลื่อนรอบการเลี้ยงออกไป เป็นอีกหนึ่งทางเลือกสำหรับผู้เพาะเลี้ยงกุ้งที่ขาดและไม่สามารถเข้าถึงแหล่งเงินทุนได้

ดังนั้น การศึกษาครั้งนี้น่าจะเป็นประโยชน์สำหรับการวางแผนและกำหนดนโยบายที่สามารถลดผลกระทบจากภัยพิบัติน้ำท่วมต่อการเพาะเลี้ยงกุ้งทะเลในพื้นที่ที่มีความเสี่ยง รวมถึงพื้นที่ต่างๆ ที่มีสภาพใกล้เคียงกับพื้นที่ศึกษา ภายใต้สถานการณ์ที่ภัยพิบัติทางธรรมชาติซึ่งเป็นผลจากการเปลี่ยนแปลงสภาพภูมิอากาศยังคงคุกขามอยู่

สาขาวิชา การจัดการสิ่งแวดล้อม	ลายมือชื่อนิสิต ________________
ปีการศึกษา 2557	ลายมือชื่อ อ.ที่ปรึกษาหลัก ________________

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KEYWORDS: SHRIMP FARMING / VULNERABILITY / FLOOD DISASTER / ADAPTATION ASSESSMENT

CHAIYAPORN SEEKAO: VULNERABILITY AND ADAPTATION ASSESSMENT OF THE SHRIMP FARMINGTO EXTREME FLOODS EVENTS : A CASE STUDY OF THE BANGPAKONG SUB-BASIN, BANGPAKONG RIVER BASIN IN CHACHOENGSAO PROVINCE. ADVISOR: ASST. PROF. CHANATHIP PHARINO, Ph.D., 188 pp.

Flood disasters associated with tropical storms have caused extensive and repeated damage to shrimp farms located in the Bangpakong River Basin, Chachoengsao Province, Thailand, which features the largest area of inland shrimp farming in the country. Chachoengsao province is a prime shrimp producing area for domestic consumption and exports, but the province is always threatened by floods. This thesis aims to assess the vulnerability of shrimp farms to flooding and recommend the adaptation options for coping with floods based on past flood events. Key factors affecting the adaptive capacity of shrimp farmers in Thailand and cost-benefit of each adaptation option are also aims of the research.

A flood vulnerability map was developed based on the geo-environmental characteristics of the study area. The map was produced through the use of geographic information system (GIS) methods and a multicriteria evaluation. The current and future vulnerability map indicates that the majority of shrimp farms in the Bangpakong River Basin are highly vulnerable to flooding when the 10-day cumulative rainfall is greater than 250-300 mm. The highly vulnerable area identified by the map is consistent with the area impacted by flooding in 2011. Key factors affecting the adaptive capacity of shrimp farmers were carried out using questionnaires and person-to-person interviews. Approximately 100 shrimp farmers who had experienced previous flood events were interviewed to help classify the impact scales of key factors on adaptation. Five socio-economic characteristics (education level, farming experience, income level, farm size, and supplemental occupations) are important factors in making the decision to apply adaptive alternatives. Latter, this research developed a flood risk map by combining the probability of flood events and vulnerability map based on physical characteristic of the area and socioeconomic conditions of shrimp farmers. Analysis of recommended risk reduction measures was performed by comparing the net benefits and costs of different strategies. Damage costs from flooding to shrimp farming were also estimated for the base case (no change in actions). The flood risk map shows that two-third of shrimp farms are highly vulnerable to flooding when 10-day accumulated rainfall is greater than 250 mm. Increasing dike height could yield higher net benefits from selling raw shrimp more than other flood adaptation measures, but it would be appropriate for flood risk areas where are likely to be flooded in every two years. Non-structural flood control is an alternative measure for shrimp farmers who lack financial means and accesses such as early harvesting and shift crop calendar.

With increasing climate change threats, these research results are useful for planning and creating policies that can reduce flood damage to shrimp farms in vulnerable zones. The results can also be applied to other areas facing similar conditions.

Field of Study: Environmental Management Student's Signature ....

Academic Year: 2014 Advisor's Signature ....

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CHAPTER 1

INTRODUCTION

1.1 Research background

Aquaculture production in Asia has grown rapidly in the last three decades, accounting for 86.5 percent in 1988, 90 percent in 1998 and 91 percent in 2010, respectively (FAO, 2010). Growing area of food production especially aquaculture may consequence from the fact that number of people on the planet rise continuously. As the world population will reach between 7.5 and 10.5 billions in the year 2050, this reason will definitely create significant demand on food in the near future (FAO, 2008). Therefore, Thailand's aquaculture has played an increasingly important role in the food security of the world and the economy of the country. For instance, Thailand's aquaculture sector has earned around 3,028 million USD in 2011, approximately 25 percent of world market share (Thailand Frozen Food Association, 2011). From this consequence, if there are negative impacts that adversely affect to aquaculture food production in Thailand, these losses may lead to future food security problem as Thailand is one of the world's major exporters of aquaculture products to USA and European countries, especially white and black tiger shrimps (FAO, 2010).

Crop yield of any agricultural products including aquaculture has declined and threaten to the sustainability, partly due to rising temperature and extreme weather events (Cruz, 2007). Recent studies on climatic extreme events as a consequence of climate change indicated that frequency of heat stress, droughts, and flood are the most serious risk to aquaculture. These stated impacts are in accordance with the results of vulnerability assessment on world aquaculture by Handisyde (2006) using Geographic Information System (GIS) to highlight areas where are the most likely to be affected. This assessment found that most countries in Southeast Asia considered vulnerable under the broad ranges of issues such as vulnerability in term of food security, vulnerability based on economic importance, vulnerability with emphasis on adaptive capacity, vulnerability of aquaculture to inland flooding, vulnerability of inland aquaculture drought, vulnerability of brackish water culture and mariculture to cyclone. Among all kinds of natural hazard in Thailand; however, floods that were likely caused by climate change are probably most devastating and frequently occur especially in the realms of monsoon season during June-September (Benfield, 2012; Limjirakan et al., 2013; Salam, 2000).

Among all kinds of agricultural products; in term of economics, shrimp is a much more highly valued product than other aquaculture and agricultural goods and has also greater market potential, but it has also higher risks from both management and natural disaster especially flooding (De Silva, 2009). Severity of flood can cause a hundred percent damage to shrimp farms because massive shrimps escape during flooding events (Muralidhar, 2010). Unlike, there are still some plants that can recover from flooding injury. In particular, Thailand is the world's largest producer and exporter of cultured shrimps. Even though shrimp production in Thailand was estimated at 250,000 tonnes which is 50% lower than the volume in 2012 due to EMS devastation, but Thailand still ranked fifth in global farmed shrimp production for 2013 (Globefish, 2014). Furthermore, Thailand shrimp farming was employing more than 1 million people with approximately 500,000 rai of land are used for shrimp farming (WorldBank, 2012). Since shrimp farming is one of the fastest growing types of aquaculture in Thailand; therefore, there should be a research to focus in assessing the vulnerability and adaptation strategies of the shrimp farms to combat to the extreme events especially floods caused by climate change.

Comparison between among extreme events under climate change, it obviously that the severity of flood causes 100 percent of damage to shrimp farm but shrimp itself may be able to tolerance the remaining extreme events such as increasing of temperature or prolong cold temperature (Muralidhar, 2010). For instance, Songsangjinda (2011) reviewed that large areas of shrimp farms in Thailand were severely impacted by floods during 2010-2011. Moreover, the current climate change impact in Bangladesh were also reviewed such as flood event inundation high as 70% comparing to average 20.5% of inundated by flood annually (Monirul Qader Mirza, 2002) and the monsoon extents from normal duration caused about 75% of its annual rainfall and cyclone that strike the coast of Bangladesh (Salam, 2000).

Currently, Fisheries Information Technology Center (2011) revealed that there are at least 25 provinces in Thailand that can culture the shrimp. Chachoengsao is the one of province where is able to culture the shrimp. The province is also recognized that they have the largest areas (rai) and largest number of shrimp farmers comparing to other provinces with the ranking in top-five of provinces that can contribute the highest shrimp production in Thailand. However, the province is located in the Central Region, which is recognized as the most vulnerability area for shrimp farming researched by Handisyde et. al. (2006) comparing to other provinces. In recent years, Chachoengsao province has been suffered and vulnerable from flooding almost every year. Details of spatial database on flood occurrence between year 2005-2010 provided by Geo-Informatics and Space Technology Development Agency (GISTDA) of Thailand was confirmed accordingly. Evidently, it is difficult to find any detailed mapping of flood vulnerable area and post-disaster mitigation supports for this region despite there is a chance of severe flood to occur in any single year. In addition, it is quite obviously that the west of Bangpakong River and near mount of river will be designated by government as the floodway to drain flooded water inundated from the Northern provinces exist to the Gulf of Thailand in order to avoid huge damage to the inner city of Bangkok. Hence, the risk to flood of the province will be worsening.

Chachoengsao province, Thailand has been selected for a case study since this province is prone to flooding. Over the past decade, the province suffered serious floods every year. The Department of Fisheries, Thailand reported that 1,514 shrimp farmers in the province experienced extreme floods in 2011 which caused approximately 109 million Baht (3.41 million US$) of damages. A report by the Chachoengsao Disaster Prevention and Mitigation Office (October 10th, 2013) reveals that all shrimp ponds (totally 1,060 with an area of approximately 640 ha) were inundated. Damage from losses of shrimp stock due to the flash floods in 2013 was estimated to be 11.88 million USD for three eastern provinces including the Chachoengsao province. The exact cost was; however, still uncertain since it was subject to the age of shrimp and current shrimp prices. Damage cost on shrimp farm may be higher than expected if harvesting is not yet carried out when shrimp attain the market size. In particular, the costs are significant for small-scale shrimp farmers who have been directly affected and are already amongst the most vulnerable members of society (Muralidhar, 2012; Muralidhar, 2010). Only supporting measure by government is that provide financial compensation for the damage and shrimp escape caused by flooding disaster. In the last 5 years, the Special Projects and Alleviation Sub-Division of Department of Fisheries spent many million baths to compensate to shrimp farmers who affected from flood in Chachoengsao province. In particular flooding crisis during September to November 2011, more than 100 million Bahts of financial assistance have been given to the shrimp farmers by the Department of Fisheries to alleviate the flood damages. Shrimp farming in flood prone areas; therefore, requires changes in practice to be more resilience (Sohel and Ullah, 2012). Adapting to the risk of flood occurrence may be the best option if the benefits obtained from the investment or building structural flood control measures outweigh its costs.

Even though majority of shrimp farms in Chachoengsao province have been flooded repeatedly, but there was little attempt to develop the vulnerability map for aquaculture sector. Also, there was no adaptation strategies used to support the shrimp farmers in preparing to cope the flood events. The main support provided by central government is to offer disaster relief fund for the flood victims. Adaptation is therefore manifestation of adaptive capacity and approach to reduce vulnerability. However, adaptive capacity or adaptability, of an affected system, region, or community to cope, adapt or recover with impacts and risks of climate change, vary significantly (Smit and Wandel, 2006; Parry, 2007; Juhola and Kruse, 2015). Until now, different methodologies used for assessing adaptive capacity have been developed. Luers et al. (2003) recommended framework to quantify vulnerability and adaptive capacity as well as the extent to which adaptive capacity can reduce vulnerable conditions especially for an agricultural and aquaculture system. Furthermore, relatively few studies comparing a relationship between adaptive capacity and socio-economic status suggest that collective socio-economic status has influenced on a chance to accept specific adaptation to reduce the vulnerability (Posey, 2009). Consequently, challenges and opportunities for more empirical studies have been emerged for assessing the relative importance of socio-economic factors associated with differential community vulnerability (Samir, 2013; Brouwer et al., 2007). With respect to the concept of adaptive capacity assessment, there is a need for an assessment of consequences how societies are likely to respond through various strategies and measures that promote recovery and modification in the long term (Kelly and Adger, 2000; Smit and Wandel, 2006; Smit et al., 2000). Moreover, there are still lacks of integration with individual, group of people and communities, who were experiences and responses to flood risks for promoting adaptation (Parry, 2002; Schmuck-Widmann, 1996). Number of studies identified constraints for adaptation in different regions and sectors (Archie, 2014; Lebel, 2013; Saito, 2013). Barriers to adaptation are not restricted to socio-economic and resource constraints. Perception of the importance of climate variability and adaptation, mal-adaptation and habit are reported as important factors for adaptation (Le Dang et al., 2014).

To address the knowledge gaps outlined above, investigation on the impact of flooding characteristics, vulnerability area of shrimp farms to floods and adaptation practices to reduce the effects of flooding in Bangpakong Sub-Basin, Bangpakong River Basin, Chachoengsao province are necessary. It is also critical to develop an adaptation and/or mitigation plan to cope with the floods that is likely to be happened every year. Lastly, provision of the economic modeling of the merits of structural and non-structural measure to mitigate the flood crisis should also be analyzed to guide shrimp farmer and policy makers for further appropriate planning.

1.2 Research problem statement

Vulnerability is a key concept for both disaster management and climate change adaptation (Cardona, 2012). Even though the concept has been studied for decades, further development is still needed (Adger, 2006; Rygel, 2006; Adger, 2004; Cutter, 1996), particularly to make connection between vulnerability, adaptation and resilience. Adoption of the concept of risk as a product of hazard and vulnerability extended to include exposure and climate change adaptation (Macchi, 2014) is also important because the most effective adaptation in future flood risk management is commonly relied upon the hazard or probability of flood occurrence. This integration of vulnerability and risk assessment is important particular for routine flood hazards which clearly require attention in both spatial planning system and public policies.

There is a need for better understanding of the effectiveness of adaptation measures to reduce future floods event. Therefore, the past flood experience, practices and its effectiveness, and adaptive strategies used to implement to combat with floods is needed to evaluate for guiding the best practices. In addition, quantifying vulnerability and adaptive capacity as well as the extent to which adaptive capacity can reduce vulnerable conditions will help to integrate disaster risk management. Scenario modeling showing interrelationship between vulnerability, adaptation and resilience can be used to provide such data (Adger, 2004).

As a result, the modeling process can contribute to the development of the economic analysis. Economic and/or cost-benefit analysis in particular of flood management measures is also a useful tool that can be used to guide shrimp farmer and policy makers to choose the best available option and/or optimum of structural and non-structural measures (Moser, 1994; Woodruff, 2008; Brouwer and Schaafsma, 2013; James, 1967).

The research questions are addressed in relation to the thesis subject and current situation of the study area. The main research question is subtracted into six questions and/or hypothesis which translate into a set of research stages. The questions and/or hypothesis are as follows:

1) What are factors affect**ing** shrimp farm's vulnerability?

2) What is the current level of shrimp farm's vulnerability in responding to flood events based on these factors?
3) What is the likelihood of vulnerability and risk changing when there are changes to some factors as a result of building adaptation capacity and climate change scenario?
4) Is there a relationship between socio-economic characteristics of shrimp farmer and decision to employ the structural approaches for adaptation?
5) What is the best available option used to combat with the flood event as a result of economic analysis?
6) How can vulnerability be incorporated into the public policy and spatial planning system in order to enhance shrimp farmer resilience to future floods?

1.3 Objectives and expected outcomes

1.3.1 Objectives

The overarching goal of this study is to develop a vulnerability and adaptation assessment for shrimp farming in Chachoengsao province. In line with this goal, there are three broad aims of this study as follows:

1) To evaluate impacts of extreme flood events to the shrimp farming and establish the vulnerability map under different future climate trends
2) To estimate damage scales and costs on overall shrimp production related to environmental and economic impacts in the study area
3) To propose adaptation strategies and guidelines for shrimp farmers in order to ensure that their practice meet the sustainable shrimp farming approach

In order to achieve these aims, the study has three specific objectives outlined below.

1) Objective 1: The climate change which may alter rainfall pattern makes a different vulnerability of shrimp farms to floods. Meanwhile, there are many factors and/or indicators that can differentiate the impacts of floods. To develop the vulnerability map, relevant indicators covered geo-physical characteristics of the study area and socio-economic are identified and used. I develop the vulnerability map under different future climate trends starting from amount of rainfall recognized as the threshold of flash flood in the study area until projected amount of rainfall in the next 50 years. Risk map which is combined between the probability of flood events and vulnerability map is also carried out as one of the objective of the study.
2) Objective 2: Results from the development of the vulnerability and risk map can be used to estimate the damage scale and costs. Not only estimated damage costs, but also cost and benefit analysis for adaptation measures are carried out.
3) Objective 3: Develop an overall adaptation strategies and guidelines by incorporating the results and suggestions obtained from the survey and results of the study. The strategy and guideline is not aim only the study area, but other shrimp farms where are likely to be flooded.

1.3.2 Expected outcomes

The overall expected outcome is benefit for both shrimp farmers and policy makers who responsible to develop strategies for increasing adaptive capacity of the shrimp farming sector. There are three main outcomes that are expected to be benefit for those interested parties as follows:

1) Vulnerability maps of shrimp farms in Lower Bangpakong River Basin under extreme flood events from future climate trends

2) To provide the economic modeling of the merits of structural and non-structural measure to mitigate the flood crisis
3) Suggested adaptation strategies and plans to alleviate future impacts from floods to shrimp farms in the study area

CHAPTER 2

LITERATURE REVIEWS

Vulnerability assessment for management of disaster risk has been examined considerably since 1980s; however, three key concepts of vulnerability assessment have not been adequately addressed as most research has been emphasized to examine on just one of them. The integration of flood disaster risk reduction and climate adaptation planning is one of the most concerned for developing as strategic policy. Therefore, this chapter will mainly discuss the vulnerability and adaptation concept within the broad literatures and research. The chapter also focuses on climate trend and their association with the flood events. On the other hand, the focus will be on the concept interpretations, current assessment practices, key results of assessment and the gaps in the previous assessment practices.

2.1 Understanding climate change

Climate plays an important role in changing the environment, natural resource, socio-economic as well as other aspects of life in all countries around the world. Variations in the climate can have substantial environmental and socio-economic implications. Therefore, climate change and its negative impacts are most serious problems for humanity and global sustainable development.

Unquestionably, human activities were caused of changing the atmospheric composition and surface properties of the earth. UNFCCC (1992) declared that “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time period”.

2.1.1 Relation of flood, extreme precipitation event and climate change

Climate change is a term that refers to major changes in temperature, rainfall, snow, or wind patterns lasting for decades or longer. Both human-made and natural factors contribute to climate change (Environmental Protection Agency, 2010). Countries, in particular tropical Asia, are likely to have increased exposure to extreme events including forest die back and increased fire risk, typhoons and tropical storms, floods and landslides, and severe vector-borne diseases (Cruz, 2007). Extreme precipitation events alone is very important, since the increase in the frequency and intensity of extreme rainfall events may cause serious impacts on both environmental and human system in terms of increased frequency and severity of floods (Arnell, 2003). The warmer temperature over the last few decades could cause the increase in both frequency and intensity of rainfall events, particularly during the summer monsoon (Limjirakan et al., 2013; Cruz, 2007). Nevertheless, from some assessment the relationship between the extreme daily precipitation intensity and the daily surface air temperature using in-situ data of Utsumi (2011) revealed that temperature relationship of the extreme precipitation intensity on a global scale is still unclear.

Many studies on impact of climate change on flood characteristics were observed, particularly in the basin level for decade. However, there are a lot of discussions on the relationship between floods and climate change. Bronstert (2003) stated that in some basin areas there is evidence of an increased risk of flooding from climate change, while in other basin areas there is no such evidence. In conclusion, there is no association between climate change and flood. Meanwhile, Chang (2010) found that flooding events will become more frequent under some climate change scenarios in the future, but climate change impacts will depend on local geomorphic condition. Hence, geo-physical characteristics of basin areas are considered as the major cause of flooding. For instance, Ghosh and Dutta (2012) was studied the impact of climate change on flood characteristics in Brahmaputra basin using a macro-scale distributed hydrological model. Result reveals that climate change influences the significant increase in both peak discharge and flood duration, particularly for both the pre-monsoonal and monsoonal seasons in the basin. The suggestion from Bronstert

(2003) also revealed that evaluation on flood risk including all relevant levels of flood risk composition, both the aspects of naturally induced hazard and vulnerability should be carried out to identify the risk areas to flood.

2.1.2 Uncertainty of climate change study

Uncertainty is intrinsic to climate change. Even though we realize that the climate is changing, but not precisely how fast or in what ways. Cox and Stephenson (2007) addressed that uncertainty in climate change projections arise from three primary sources:

1) *Natural climate variability*: it is resulted from natural processes within the climate system which cause changes in climate over relatively short time scales
2) *Future emissions of greenhouse gases*: arising from uncertainty over the scale of future global emissions of greenhouse gases by human society. Thus, the scale of future GHG emission becomes a dominant source of uncertainty on time scales of 50 years or more.
3) *Modelling uncertainty:* arising from incomplete understanding of Earth system processes. Incomplete representations of these processes in climate models are also outcome of uncertainty.

Modeling uncertainty in particularly is another source of uncertainty for adaptation planning. Different climate model produces different projection as well as represents these processes in different ways. Although climate change impacts and agricultural adaptations have been studied extensively, how smallholder farmers perceive climate change and adapt their agricultural activities is poorly understood (Yu et al., 2014).

2.2 Overview of shrimp farming production development in Thailand and study area

Traditional method of marine shrimp culture, with so called “extensive” has been practiced in Thailand for more than the last 80 years starting in the upper gulf of Thailand (Tookwinas, 2005). Shrimp production from this type of culture is relied on both the traditional low density method of wild shrimp gained by opening the gates and impounding its wild larvae and the natural productivity of the pond as feed for wild shrimp. Due to the demand of shrimp products from international market has increased during 1985-1988; however, the traditional shrimp culture was replaced by more productive practices either semi-intensive or intensive shrimp culture to serve global market. For the practice under semi-intensive shrimp culture requires pond enclosures, shrimp fry from hatchery with high stock density at 6-25 PL/m^2, manuring and fertilization, water exchange, usage of aerator, use of high nutritive feeds and usage of drugs and chemicals. For intensive shrimp culture is quite similar to semi-intensive but requires high financial, technical inputs, higher stocking density at 25-35 PL/m^2, better water exchange, drainage and removal of sludge (Szuster, 2003; Tookwinas, n.d.).

From the global demand on shrimp products and technology of either semi-intensive or intensive shrimp farming which has expanded significantly in the last two decades, shrimp farms has rapidly expanded to along the coastal provinces in the central, eastern, and southern part of Thailand in the last 2 decades. Its consequence has led Thailand become the world’s leading exporter for shrimp products continuously for several years (Manarungsan, 2005).

Current practice of shrimp farming in the study area, Lower Bangpakon River Basin, Chachoengsao province, are vary depending on production techniques and can be classified into three categories; extensive (traditional), semi-intensive and intensive based on cultured area, yield and stock density (Tookwinas, n.d.). Extensive shrimp farming in Chachoengsao province was; however, changed to intensive practice of inland shrimp farming (Marhaba et al., 2006). Under semi-intensive shrimp culture utilizes pond enclosures having rectangular in shape with an area of about 1-8 hectares. Number of shrimp farms and total farm areas with intensive system are greater than either semi-intensive or extensive system since the early 1990s (Barbier, 2004) but the significant impact of disease and environmental pollution from the intensive practice caused by improper management and incompliance with the an environmental best management practices are much greater than in extensive and semi-intensive system.

2.3 Observed impacts from climate variability (change) to shrimp farms

Effects of climate variability to aquaculture especially marine shrimp farming are quite obviously. Its effect caused serious damage to the country's economic and livelihood of shrimp farmers who have been affected. Songsanginda (2011) has revealed that shrimp farms in southern part of Thailand were severely impacted by extreme flood during late 2010 and early summer of 2011. The impact of this variable climate destroyed farm production which estimated the loss at least 60,000 tons of shrimp production or equal to 350 million US$, shrimp facilities, and cause of the outbreak of diseases from both virus and bacteria in the farmed shrimps. Moreover, from the newsletter of Thai Frozen Foods Association (May, 2011) addressed that an issue of climate variability in the eastern of Thailand occurred in March 2011 caused an unusually prolonged period cold temperature that was the result of clinical sign of shrimp health, reduction of water quality, disease outbreak specially white spot syndrome virus and the loss of shrimp production.

Not only direct impacts which include changes in the temperature and increased frequencies of extreme events (such as flooding and storm surges) which caused 100 percent of damage to shrimp farm (Muralidhar, 2010) but also indirect impacts related to loss of economic due to damaged pond need to be treated before new stocking, reduce the revenue related to increasing of fishmeal costs with consequences for increasing of aquaculture feed cost, and negative impacts i.e. increase stress of shrimp, increase frequency of diseases and toxic events, increased food conversion efficiencies and increased length of the growing season are the consequences caused by climate variability or change (Cochrane, 2009; Kapetsky, 2007).

2.4 Types of floods

An extreme flood is an extraordinary flood with severe consequence for man or nature (Lundquist, 2002). A distinction of types of floods can be made between four different: coastal floods, river floods, flash floods and urban floods (Balica, 2012).

1) Coastal floods; it can be happened all along the coast and also alongside banks of large lakes. Floods usually occur when storms coincide with high tides and can include overtopping or breaching of beaches. Coastal flooding may also happen by sea waves called tsunami. Tropical storm and hurricanes can generate serious rains or drive ocean water into land.

2) River floods; it occurs when the spring rains and with winter snows melt merge. The river basins are filled too fast, and then the stream will spill over its banks. River floods can also occur because of heavy rainfall for a period of days over a large area.

3) Flash floods; they are temporary inundations of different areas such as: river basins, sub-catchments and a town or parts of a city. Short period of intense rain can cause flash floods, they usually occur in combination with thunderstorms and over a very small area. The ground is not usually soaked; but at the rainfall intensity exceeds the infiltration rate, the water runs off the surface and soon collects in the receiving waters.

4) Urban floods; this flood is usually caused by extreme local rainfall, combined with blocked drainage systems. This type of flooding depends on soil and topographical conditions and the quality of the drainage system. These floods are the effect of urban/suburban sprawl, where urbanized land is not capable of rainfall absorption.

The floods in Thailand, in particular extreme flood occurred in 2011, were spawned by the start of the typical monsoon season which brought continued elevated rainfall to central and northern sections as flash floods, river flooding and landslides (Benfield, 2012). Flash flood caused by overflow through spillway and the collapse of a human structure such as dam or reservoir failure is severely affect to social, environment and economic development as well as may not be useful for flood warning (Seoduangsine, 2012; Petchprayoon, 2001).

2.5 Vulnerability and adaptation

2.5.1 Vulnearbility

The IPCC defined vulnerability in the context of climate change as: "…the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sentivity, and its adaptive capacity" (Parry, 2007).

On the other hand, Cannon (1994) addressed that "vulnerability is a measure of the degree and type of exposure to risk generated by different societies in relation to hazards. Vulnerability is the a characteristic of individuals and groups of people who inhabit a given natural, social and economic space, within which they are differentiated according to their varying position in society into more or less vulnerable individual and groups.".

Cutter (1993) says that "vulnerability is the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards of place (risk and mitigation) with the social profiles of communities". Meanwhile, Richards (2005) indicated that "vulnerability is susceptibility to harm or damage potential. It considers such factors as the ability of a system to cope or absorb stress or impacts and to "bounce back" or recover.".

Since the early 1980s, the concept of vulnerability has been studied across a wide range of disciplines of demography, geography, human ecology, economic, anthropology and psychology (Marandola and Hogan, 2006; Adger, 2006). The topic has been approached from both natural science perspectives and social science perspectives. On the other hand, it would be addressed that the study of vulnerability can be described as a multidisciplinary concept.

The multidisciplinary concept to the vulnerability assessment leads to a interchangeable meaning with other key two concepts of resilience and adaptation. Although there was argument on the different interpretation of some of its basic terminology, Cutter (1996) and Adger (2006) argue that disciplines are the most importance of the concept for vulnerability assessment. Cutter (2008) also reveal that the connection between vulnerability, resilience and adaptation can be summarized as shown in Figure 2.1.

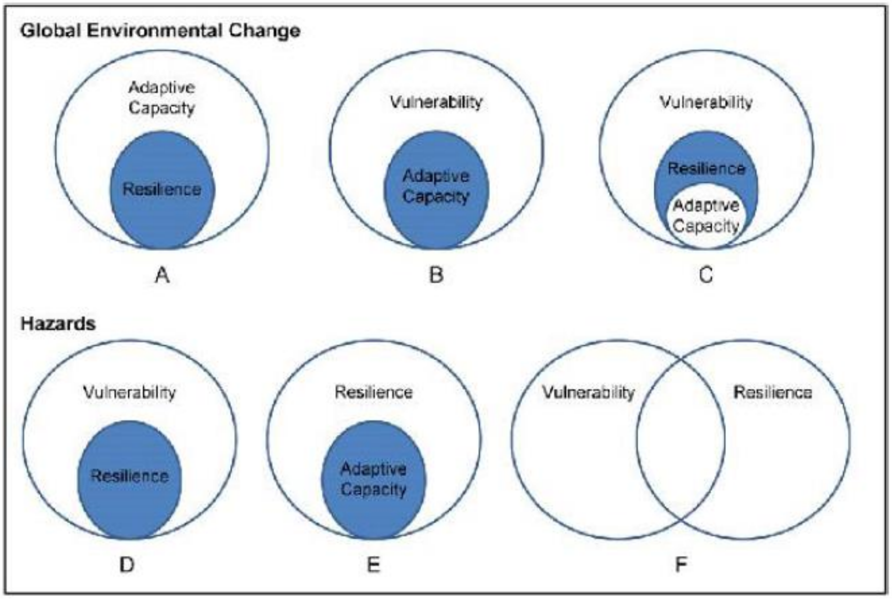

Figure 2.1 Conceptual linkage between vulnerability, resilience and adaptation (adopted from Cutter et al. (2008))

Even though three concepts for the purpose of community vulnerability modeling focus on community capacity to cope with hazard, vulnerability is often observed as a state of community capacity in a specific time and place. Therefore, vulnerability assessment should be focused on the single time frame and geographic area.

Climate change vulnerability assessment examines the essential socio-economic, institutional, and political and cultural factors that influence vulnerability.

On the other hand, vulnerability that made shrimp farmers being affected by extreme events under climate change will be determined by three factors: their exposure to specific change, their sensitivity to their change, and how well they respond and/or adapt to impacts (Figure 2.2). There is not much difference between conceptual linkage of Cutter et al. (2008) and conceptual model for vulnerability adopted from Bell (2011) and Cochrane (2009). In this study, conceptual model for vulnerability showed in Figure 2.2 will be used as the concept for differentiate the meaning of vulnerability from other key concepts under different specific time (current and future). Furthermore, the meaning of vulnerability will be used to position the concept within disaster risk management.

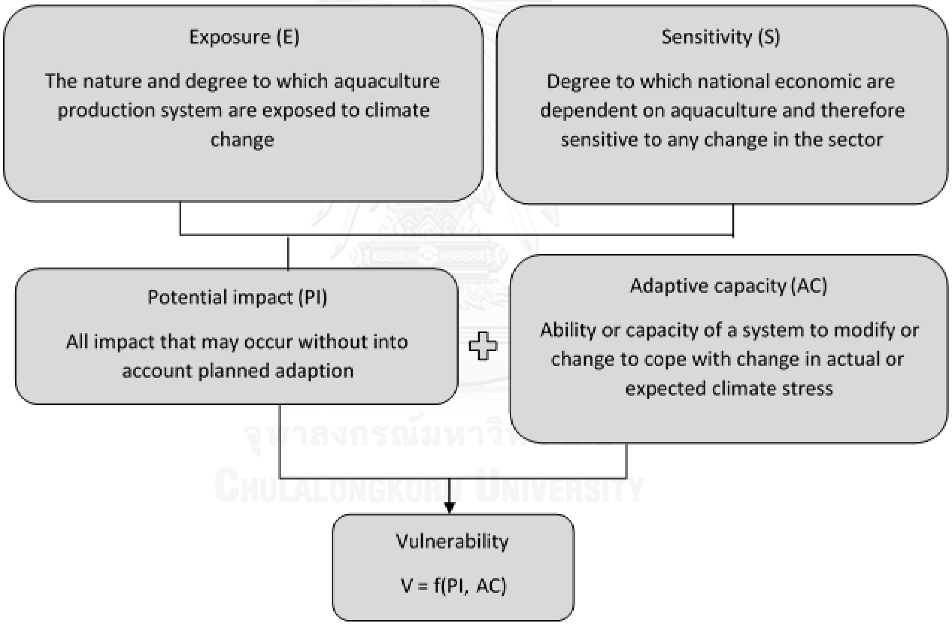

Figure 2.2 Conceptual model of vulnerability

Source: Adopted and modified from Bell et al. (2011) and Cochrane et. al. (2009)

Vulnerability with regard to climate change implies that organisms are exposed to aspects of climate that are changing in ways that will either generate or increase risk, which generally implies a potential loss of something valued (Glantz, 2009). The capacity to cope with the risky situations under a given exposure to hazard can shape the pattern of vulnerability.

Hung (2012) addressed that three characteristics of vulnerability; exposure, sensitivity and adaptive capacity, are expressed by the vulnerability indicators to indicate specific sectorial baseline, to create vulnerability profile and to assess impacts regarding different climate change. The framework comprises of 3 components as following:

1) The assessment of hazard of global climate change; flooding and inundation, storm surge, salinity and etc.
2) The assessment of the potential impacts (sensitivity) on human systems and natural resources
3) The identification of adaptive capacity at the provincial and district level as the boundary of administration by the survey and questionnaire of districts and provincial level's authorities.

Vulnerability management generally aims to reduce society's vulnerability to natural disasters and unavoidable consequences of climate change by taking several types of actions (Füssel, 2006). Balica et al. (2013) defined vulnerability specifically related to flooding as "the extent to which a system is susceptible to floods due to exposure, a perturbation, in conjunction with its ability (or inability) to cope, recover, or basically adapt". The concept of vulnerability is therefore set as a function of three interdependent components: (i) the exposure of systems to the potential effects of climate change; (ii) the sensitivity of the systems to climate change or other stressors; and (iii) society's capacity, or the adaptive capacity, to adapt these current systems to changes in social conditions (Kapetsky, 2007; Gallopin, 2006). Meanwhile, the adaptive capacity concept that has specifically been used in climate adaptation studies is defined as the extent to which the system has the ability to cope with the projected impacts of climate change and reduce vulnerability (Adger, 2006; Smit and Wandel, 2006; Parry, 2007). In this context, adverse declines in the regional food supply in South Asia, which is one of four areas of possible dangerous climate change, are of particular concern (Hare, 2011). The adaptive capacity is directly connected to social and economic development (IPCC, 2007). A system's adaptive capacity and coping range are not static, meaning that they are flexible and respond to changes in economic, social, political and institutional conditions over time (Smit and Wandel, 2006). For instance, population pressure due to a lack of income diversification in the system (community) and access to financial resources gradually reduces a system's coping ability and narrows its coping range, while economic growth in the system may lead to an increase in the adaptive capacity (Smit and Wandel, 2006; Ibarrarán et al., 2010).

2.5.2 Adaptation

Adaptation is an important approach for the protection of human and natural systems from the risk posed by climate variability as well as for exploitation of beneficial opportunities that may be provided by a climate change. On the other hand, adaptation measures or processes can offer a means of coping to climate change impacts.

The following section outlines a number of terms that provide information to the adaptation works. The definitions for key terms adopted by the IPCC (2007) as presented below:

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harms or exploits beneficial opportunities

Adaptive capacity: the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequence

Exposure: The nature and degree to which a system is exposed to significant climatic variations. For example, the more people move to low-lying coastal areas, the greater is the population's exposure to SLR and increased coastal storms

Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change

Sensitivity: Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability to temperature) or indirect (e.g, damages caused by an increase in the frequency of coastal flooding due to sea level rise).

2.5.2.1 Adaptation options

Many types of adaptation come in a wide variety of forms. Table 2.1 illustrates the types of adaptation and general concepts. Furthermore, adaptation can be either reactive or anticipatory depend on degree of spontaneity (Smit et al., 2000).

Table 2.1 Characterizing and differentiating adaption to climate change (Smit, 2001).

Differentiating concepts	Examples of terms used
purposefulness	Autonomous ← → planed Spontaneous ← → Purposeful Automatic ← → intentional Natural ← → Policy Passive ← → Active strategic
Timing	Anticipatory ← → Responsive Proactive ← → Reactive Ex ante ← → Ex post
Temporal Scope	Short term ← → Long term Tactical ← → Strategic Instantaneous ← → Cumulative
Spatial scope	Localized ← → Wide spread
Function / Effects	Retreat – Accommodate –Protect Prevent – Tolerate – Spread – Change - Restore
Form	Structural – Legal – Institutional – Regulatory – Financial – Technological
Performance	Cost – Effectiveness – Efficiency – Implementability - Equity

Source: adopted from Smit et al., 2001

The increasing interest for adaptation is reflected in the evolution of the theory and practice of vulnerability assessment. Füssel (2006) reveal that the effectiveness of adaptation is depending on the availability of two conditions: information on what to adapt to and how to adapt, and resources to implement the adaptation measures. Furthermore, Brooks (2005) confirmed that the vulnerability of a system to climate change, that is associated with anticipated hazards in the medium to long term, will depend on that system's success at anticipatory adaptation. Then, adaptation could be considered as attempt to change on economic, social and political structure (Smit and Wandel, 2006). In addition, any adaptation **policies** should have to contribute to the existing occurrence that communities face.

Adger et al. (2005) examined the criteria for the decision of successful of adaptation. The element of effectiveness, efficiency, equity and legitimacy are important in term of sustainable development into an uncertain future. The factors that affect adaptive capacity include a set of indicators of adaptive capacity. Brooks et al. (2005) reveal that adaptive capacity is associated with indicators of governments, civil and political rights, and literacy. However, measure of wealth is also importance. As adaptation does not happen suddenly, the relationship between adaptive capacity and vulnerability is subject to timescale and hazards. Smit and Wandel (2006) reviewed the concept of adaptation in the context of adaptive capacity and vulnerability of community system. Hence, adaptations which are change in the system to deal with problematic exposure and sensitivities are manifestations of adaptive capacity.

2.5.2.2 Adaptation capacity

Adaptive capacity is the ability of a system to respond to climate variability and change. Brooks and Adger (2005) address that adaptive capacity is a prerequisite for the design and implementation of adaptation strategies to reduce the likelihood and magnitude of devastation resulting from climate change. However, the adaptive capacities of societies are not always the same, and vary from community to community and among groups and individual, and over time, reported in the IPCC (2007). Therefore, adaptive capacity is not a static element. Smit and Wandel (2006) defined that adaptive capacity is the condition of a system to deal with accommodate, adapt to and recover from.

Adaptation is a manifestation of the adaptive capacity and the approach for reducing vulnerability. However, the adaptive capacity, or adaptability, of an affected system, region, or community to cope with, adapt to or recover from the impacts and risks of climate change varies significantly (Smit and Wandel, 2006; Juhola and Kruse, 2015; Parry, 2007). Different methodologies for assessing adaptive capacity have been developed. Luers et al. (2003) recommended a framework for quantifying vulnerability and the adaptive capacity as well as the extent to which the adaptive capacity can reduce vulnerable conditions, especially for an agricultural system. Furthermore, relatively few studies comparing the relationship between the adaptive capacity and socio-economic status suggest that the collective socio-economic status influences the chance of accepting specific adaptations to reduce vulnerability (Posey, 2009). Consequently, challenges and opportunities for more empirical studies have emerged regarding assessing the relative importance of socio-economic factors associated with differential community vulnerability (Samir, 2013; Brouwer et al., 2007). With respect to the concept of adaptive capacity assessment, there is a need for assessment of the consequences of how societies are likely to respond through various strategies and measures that promote recovery and modification in the long term (Kelly and Adger, 2000; Smit and Wandel, 2006; Smit et al., 2000). There is still a lack of integration with individuals, groups of people and communities who experience and respond to flood risks to promote adaptation (Parry, 2002; Schmuck-Widmann, 1996). The integration of scenario development processes with an interactive modeling platform is therefore illustrated to allow the exploration of future uncertainly and to explore adaptation choices within real-world constraints (Harrison et al., 2013). However, a number of studies have identified constraints on adaptation in different regions and sectors (Archie, 2014; Lebel, 2013; Saito, 2013). Barriers to adaptation are not restricted to socio-economic and resource constraints. The perception of the importance of climate variability and adaptation, mal-adaptation and habits are reported as important factors for adaptation (Le Dang et al., 2014).

To examine factors influencing the adaptive capacity, it is important to understand the diverse set of indicators used to quantitatively assess the conditions of a system under different vulnerabilities (Balica, 2012; Balica, 2009). Two distinct types of indices are considered in this article: physical vulnerability and social vulnerability. The first index is used in the assessment of areas exposed to flood hazards and integrates a number of geo-environmental characteristics to determine the overall physical vulnerability of an area (Dewan, 2013). GIS-based approaches that allow coherent assessment of physical vulnerability toward flood hazards are widely used (Kappes et al., 2012). Although physical vulnerability can be assessed in the absence of social vulnerability (Uzielli et al., 2008; Douglas, 2007), exposure and sensitivity are inseparable properties of a system and are dependent on the interaction between the characteristics of the system and on the attributes of the climate stimulus (Smit and Wandel, 2006). The second index, associated with the assessment of the social characteristics of the system, has evolved over the last decade. An efficient social vulnerability assessment requires the determination of baseline data on socio-economic characteristics and the experiences of communities and individuals that enable them to cope with natural hazards (Cutter, 2003; Cutter, 2008). The population characteristics and socio-economic conditions of particular areas are used to assess social vulnerability based on a composite index of these indicators (Fekete, 2009). The social indicator aggregation method is widely used in assessing social vulnerability to natural disasters. Therefore, the reduction of social vulnerability to environmental hazards is a consequence of the emerging realization of the adaptive capacity as adaptation, while the reduction of physical vulnerability or risk will depend on the evolution of hazard levels (Adger, 2004). A combination of physical and socio-economic indicators can shape the overall vulnerability of a particular area to floods (Dewan 2013; Santos et al. 2013) and can be used to determine hazard levels that may occur in an area where human systems are well adapted (Adger et al. 2009).

2.6 Historical development of vulnerability and adaptation assessment

Understanding the history of vulnerability assessment could result in several guides for future research in the area of vulnerability assessment. Many literatures were adopted to study for the history of vulnerability assessment such as Barnett et al.

(2008); Adger (2006); Rygel (2006); Adger et al. (2004); Luers et al. (2003) and Cutter (1996).

The first guidance is a convergence between physical science and social science which could make clear in understanding the historical development of vulnerability assessment. Evidence from the works of Marandola and Hogan (2006) showed that they have assessed vulnerability from both the environment (biophysical) and socioeconomic perspectives. Cutter (1996) also suggested to integrate between “vulnerability as hazard of place” and the perspective of “vulnerability as a pre-existing condition” and “vulnerability as a tempered response”. Key characteristic of vulnerability; biophysical vulnerability and social vulnerability could combine with geographic context, social and hazard potential (Cutter, 1996). Having integration from different perspectives enhances the quality of vulnerability factors as it is first thing need to be identified for determining the level of vulnerability. As a result, the level of vulnerability from convergence between environment and social sciences will better represent the performance of any case study.

Connecting with policy in vulnerability research becomes key challenge in vulnerability assessment. How to reduce the impact from natural hazards is one of key priority of policy decision maker. The relationship between vulnerability and public policy has recently been studied. The discussion on linkage assessment between policy making and vulnerability is still one of the main challenges revealed by some literatures Marandola and Hogan (2006), Adger (2006) and Adger et al. (2004). In relation to the integration between vulnerability and public policy, Luers et al. (2003) indicate that a combination of vulnerability, adaptation and resilience concepts is challenge for future research on vulnerability. Integration process of adaptation and vulnerability by stressing public policy for reducing future vulnerability level is needed (Adger, 2006). The integration concept can be made through vulnerability modeling in the future assessment processes. Adger et al. (2004) proposed that integrating assessment of vulnerability and adaptation can be conducted by a modeling approach. This approach also often results in the mapping of vulnerability to certain hazards. However, mapping of vulnerability is required clearer approach to vulnerability factor selection (Rygel et al., 2006). Then the results of vulnerability assessment are considered as the source for policy decision makers.

The systemic approach is growing issue and can be seen in the several works. Here below are the examples of the history of flood vulnerability assessment:

2.6.1 Flood modeling, remote sensing and geographic information system

Kapetsky and Manjarres (2007) addressed that the model to assess the vulnerability sets vulnerability as a function of exposure and sensitivity to climate change and adaptation capacity. The analytical procedure can be implemented by each production function (layer). They will be reclassified so that its cells have an importance ranging from 1 to 5 and have a data layers in the sub-model. The another data layers in the sub-model and main model can be combined using multi criteria evaluation (MCE) with weighted linear combination and with the weights placed on layers determined by expert opinion.

Yahaya (2010), Lawal (2012) and Musungu (2012) have used Geographic Information System (GIS) integrated with multi criteria evaluation (MCE) to analyze the flood vulnerable areas in their research. GIS application is used for managing, producing, analyzing and combining spatial data which obtaining from the conversion of collection or existing data by using spatial functions and analysis. There are many approaches to evaluate the flood vulnerable areas using GIS and MCE. The famous approaches are Boolean overlay approach and Weighted Linear Combination (WLC) approach. These approaches allow classification and weighting to evaluate the criteria that may alter to flood vulnerability area. In evaluating the flood susceptible areas, pair-wise comparison method in which is integral part of Analytical Hierarchy Process (AHP) proposed by Saaty (1980) is used for tackling sophisticated problems. It helps in detecting the flood vulnerable areas by identifying the most flood significant criteria based on the decision makers's preference. Because of the reason of individual judgments will never be agreed perfectly; however, the degree of consistency measured by a Consistency Ratio (CR) that can also be implemented in GIS is outstanding to ensure accuracy of the data.

2.6.2 Forecast Scenarios

At this moment, most of strategic alternative are focusing on vulnerability reducing. So, new questions are needed to be answered is that what will be happen in terms of vulnerability when condition changes (future scenarios) and what happens if a set of vulnerability mitigation measure (strategic alternatives) is carried out (Benedetto, 2010). This is implied that the creation of meaningful future scenarios, in which acceptable drivers of future change, and potential management response to these results are necessary. Scenarios can help decision maker to create contingency plans for possible future. On the other hand, scenarios are like contingency plan but they have a limited shelf life[1:] Because of their relatively short shelf life and because of societies and climate are constantly changing; therefore, scenarios need to be revisited, critically reviewed and updated periodically at regular intervals.

There are many way to create scenarios for the assessing the vulnerability to flood. Glantz et. al. (2009) addressed that the creation of scenarios such as forecasting by analogy is a popular approach to attempt in obtaining a result of the future. Benedetto and Chiavari (2010) applied five scenarios to assess the vulnerability to flood: the current scenario and four future scenarios that have no mitigation measures scenario as the one of future scenario. Zhang (2003) applied to a hypothetical dike break case study due to the different return period rainfalls, so scenario generating includes basic (design) flood estimation and dike break condition. Moreover, there is another method to simulate scenarios by applying the influence of land use change

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[1] This means that the result predicted by using scenarios or even worst case scenario prior for a year or longer may become a distant memory to planners by the time that extreme event has formed to start revealing the impact in the next few days

on flood occurrence and severity. These scenario simulations will be made for a different period of time: pre-industrial, an intermediate and a current year.

2.6.3 Adaptation assessment

Cochrane et al. (2009) addressed that options to increase resilience and adaptability through improved aquaculture management include the adoption as standard practice of adaptive and precautionary management. The ecosystem approaches to aquaculture (EAA) should be adopted to increase the resilience of aquaculture production system. In the case of aquaculture, applying an ecosystem based approach must involve physical, ecological, social and economic system in the planning and assessing the adaptation (De Silva and Soto, 2012). They must also take into account the stakeholder capacity and experience.

As impact assessment assumes adaptations to estimate damage to longer term of different climate scenarios, participatory vulnerability assessment is the one of method to identify adaptation strategies that are feasible and practical in communities on risks as well as are already problematic. (Smit and Wandel, 2006). Dessai (2005) revealed another way to examine how climate scenarios fit in different broad adaptation frameworks which compose of; the IPCC approach, risk approaches, and human development approaches. It showed that adaptation approaches depend on availability of technical and financial capacity to handle scenario information, and the type of adaption being considered. For coping strategies to climate change of shrimp farmer, Abery (2011) addressed that shrimp farmers in Vietnam have started to combat too much rain and associate water quality and disease problems by further implementing of research on new technology, culture practices at different salinity levels, research about pond natural food chains and etc. However, there are no measures to combat flood occurrence. Only identification of pollution types and sources that impact on aquaculture when flood occurs and research on engineering aspects of pond design are taken into account. MRC (2009) also revealed the adaptation measures for aquaculture but they indicated only the adaptation to high temperature, sea level rise, and frequency and severity of storms but not for adaptation measures to flood. However, Szuster (2006) suggested that aquaculture zoning and other forms of integrated management not only could combat from pond flooding caused shrimp escape but also mitigate potential impacts related to soil salinization and restrict shrimp farm to less productive agricultural area.

2.7 Modeling approaches

In recent years, many efforts have been made to use geographic information system (GIS) integrated with the multicriteria evaluation for identifying the vulnerable areas toward floods (Yahaya et al. 2010; Lawal et al. 2012; Musungu et al. 2012). GIS and multi criteria decision analysis has been competent in natural hazard analysis for many geo-environmental studies and is a process that combines and transforms geographical information into different datum for further judgment from decision makers (Fernández and Lutz, 2010; Dai et al., 2001; Malczewski, 1999).

However, this useful tool has never been used to assess the vulnerability area for aquaculture zoning in Thailand. Investigation on the impact of flooding characteristics, vulnerability area of shrimp farms to floods and adaptation practices to reduce the effects of flooding in Bangpakong Sub-Basin, Bangpakong River Basin, Chachoengsao province are necessary because the area is ranked in the top-five province contributing to the highest shrimp production in Thailand. The research purpose is therefore to assess the vulnerable zones of shrimp farms that are likely to be inundated by flood and investigate recent adaptation practices of shrimp farmers to cope with previous floods. Multicriteria Evaluation and Geographic Information System (GIS) are used in this study to assess the vulnerability of shrimp farms towards floods, to classify non-flooded areas, and to delineate previous adaptation practices of shrimp farmers to cope with flood at district level. The high spatial resolution of the flooded areas delineated by the GISTDA of Thailand helps generating details suitable for developing adaption plan on a particular scale. This study would greatly illustrate and enhance the capability of using the spatial database to assess the vulnerability of shrimp farm for accurate detail planning to alleviate impacts from extreme flood events in the future.

The context for environmental modeling is presented here as a review of the existing literature. Following are parts of modeling approaches used to focus for this study. Firstly, Geographical Information Systems (GIS) used for geospatial data management and analysis are revised. Secondly, Multi-Criteria Evaluation under the AHP is provided.

2.7.1 Geographic Information System (GIS)

Geographical model have been using in the form of maps and globes. GIS has developed into the communication of geography for people. Geography encompasses both the physical and cultural. The expansion was achieved through the content automation inserted into geographic processes. As a consequence, new concepts and methods have been introduced into interactive mapping, reprocessing, integrating data, visualization and modeling (ESRI, 2010).

Many definitions have given to describe GIS. However, Geoscience Australia gave a definition of GIS as presented following:

GeoscienceAustralia (2008) reveals that "GIS is a mapping software that provides spatial information by linking location with information about that location. It provides the functions and tools needed to efficiently capture, store, manipulate, analyse, and display the information about places and things"

Yeung (2000) addressed that the function of an information system is to convert data into information as details below:

1) Conversion: transforming data from one format to another or from one unit of measurement to another
2) Organization: organizing or reorganizing data according to database management procedures
3) Structuring: formatting or re-formatting data until it is acceptable to a particular software application
4) Modeling: statistical and visualization will be used to communicate with user in decision making

There are four components of GIS: geographically referenced data, a computer system, software, and people (Chang, 2010; Yeung, 2000; Grinderud, 2009). Geographically referenced data refers to locations and characteristics of natural features. Spatial and attribute data are two main component of geographically referenced data. Location represents spatial data, while attribute data presents characteristics of the spatial data in the form of attribute data. A computer system refers to hardware used for production of map. GIS software includes the programs and the user interface for driving the hardware. GIS software is supplied by a range of suppliers. Lastly, people are as most important from other components of GIS.

There are two common ways to represent the entities of geographic; vector models and raster models as described below (Goodchild, 1993).

1) Vector model are coordinate-based data models that represent geographic entities as points, lines and polygons. These geographic entities are stored by using coordinate pairs (points) that reference locations on the Earth’s surface.
2) Raster (or grid) models represent geometric entities as cell values. Rectangular grid of cells is draped over geographic feature and every cell is coded on what the grid represents.

2.7.2 Multi-Criteria Evaluation (MCE) and Analytical Hierarchy Process (AHP)

Decision analysis lies at the core of the environmental policy making process. Decision making happen when problem requires an actions among various options to generate a solution. “Choice” and “alternatives” are two defining key elements in the decision process. Most of decision processes regarding the environment are complex and involve multiple criteria. In term of multicriteria evaluation, a problem can be considered as a problem if there are at least two criteria to deal with and it will become a problem of getting the right information (Keeney, 1976). Despite the fact that most of environmental issues involve the consideration of multiple-ceriteria problems, it seems not handling accordingly. Therefore, making a choice among criteria needs to be identified satisfied goal. Then, trade-offs are inevitable in the decision making process (Keeney, 1976).

As a consequence, multi-criteria evaluation constitutes an advance field of operation research. Its objective is to aid for making realistic decision by taking various multiple criteria into consideration. However, multi-criteria evaluation technique also requires taking the AHP method into account. The acronym AHP stands for “Analytical Hierarchy Process”, originated by Saaty (1980). The method was created to assist an individual in decision making to choose an alternative among criteria. Numbers of decision making players are needed to consider. Hence, judgments are obtained from a group of people. However, if all numbers are considered equal, weighted geometric mean would be used to synthesis the reciprocal judgments in AHP.

The underlying concept of the AHP technique is to convert subjective assessment to set of overall scores and weights. Therefore, Saaty (1990) describes the AHP technique in following: “Basically, the AHP **is** method of breaking down a complex, unstructured situation into its component parts, or variables, into a hierarchic order; assigning numerical values to subjective judgments on the relative importance of each variable, and synthesizing the judgments to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation”

Furthermore, (Schmoldt (2001)), Vaidya and Kumar (2006) and Render (2006) defined the principle for AHP as following:

1) Decomposition to enables decision makers to structure a problem into a hierarchy that consists of goal and features.
2) Evaluation using pair-wise comparisons between elements at each level to enable a preferential ordering of decision elements.
3) Synthesis, which involves matrix algebra that circulates level specific, local priorities to global priorities.

CHAPTER 3

METHODOLOGY

3.1 Case study description

3.1.1 Characteristic of Bangpakong River Basin

The Bangpakong Sub-Basin is the main part of Chachoengsao province (Figure 3.1) and is passing through by Bangpakong River. Bangpakong River Basin hosts a wide range of activities involving agriculture and fishery for decades. For instance, highly productive from shrimp farming and other agricultural products especially irrigated rice, are the main products of this fertile land along the Bangpakong river bank (Szuster, 2002). Regarding to geo-physical characteristic of study area, the study area is located in a low basin of Bangpakong River Basin. This basin is located downstream from between Prachinburi River and Nakhonnayok River before flowing into the Gulf of Thailand. This low basin has a very limited capacity to control extreme hydrological events from the upper catchment of Prachinburi River and Nakhonnayok River as well as its tributaries. Consequently, Bangpakong Sub-Basin has received and overflown by huge mass of water from both rivers.

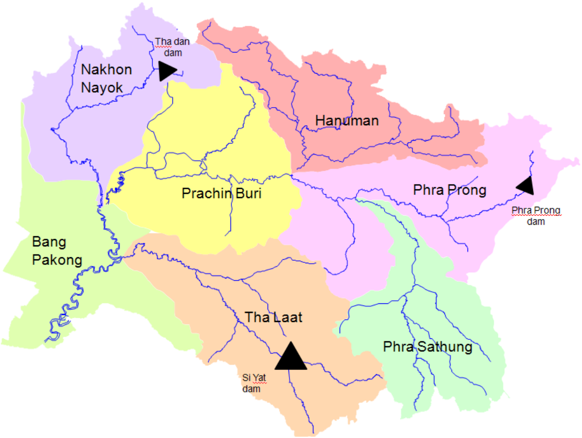

Figure 3.1 The Bangpakong sub-basin located in the study area (Chachoengsao province)

The Bangpakong River Basin covers an area of 18,670 square km. The area's topography ranges between 0 to 84.9 meters above sea level. Rainfall varies between 1,000 and 2,000 mm and most of the runoff (8.6 billion m^3 or Bm^3) approximately 60% is generated in the Northern sub-basins (Nakhon Nayok, main Prachin Buri, Hanuman). However, only 10% of runoff occurs in the dry season. As irrigation areas in the basin are connected in the lower part of the basin, storage capacity allowing water use in the dry months of the year is necessary. Nowadays, there are three reservoirs (indicated as black arrow in the Figure 3.1) which compose of; the Nakhon Nayok or Tha dan (225 Mm3), the Phra Prong (110 Mm3) and the Si Yat dam (376 Mm3) that can be used to store the rain and runoff from flood events. Moreover, there are many benefits from reservoir which are not stored the rain and runoff from floods but also irrigate water for agricultural fields, particular from Nakhon Nayok reservoir.

3.1.2 Flood events in Chachoengsao province

Although the declining trend in average annual rainfall in the basin which normally ranges between 1,100 mm to 1,200 mm was observed by Thai Meteorological Department, but the intensity of precipitation events will likely increase on average. Consequently, the number of previous flood events observed in the last decade showed that shrimp farms in the study area were flooded 7 times in the last 9 year: 2005, 2006, 2008 (2 times in 2008), 2011, 2012 and 2013. High precipitation over a short period of time is cited as the most important factor responsible for triggering severe flooding in Bangpakon River Basin. Therefore, Lower Bangpakong Sub-Basin is the flood prone area. Most recently in the last 3 years, Chachoengsao province was reported that flood occurs every year.

Since Thailand suffered from extreme flood for several months in year 2011; in addition, it was important issue for the government to make a decision to designate the floodway in order to drain flooded water from the Northern provinces to the sea as quick as possible. This floodway can also prevent the devastation of floods to be affected in inner of Bangkok and main commercial areas. Currently, it is obviously that the area in the west of Bangpakong River and near mount of river will be designated by the government to be floodway (Figure 3.2).

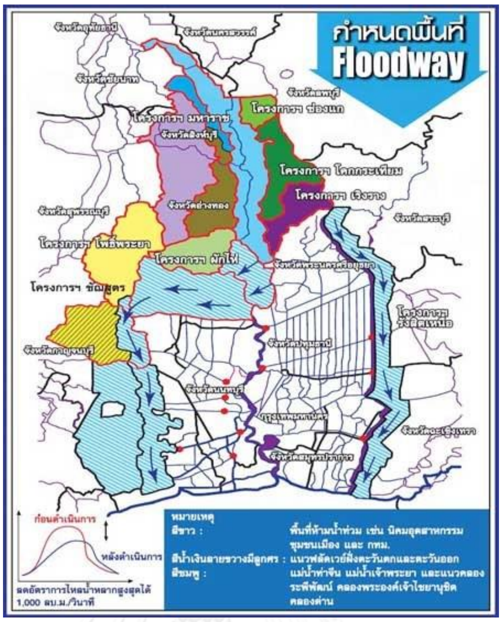

Figure 3.2 The proposed floodway for year 2012

Source: Ministry of Agriculture and Cooperatives (released on 21 February 2012)

3.1.3 History of shrimp farming in Chachoengsao province and flood characteristics

Traditional method of marine shrimp culture, with so called “extensive” has been practiced in Thailand for more than the last 80 years starting in the upper gulf of Thailand (Tookwinas, 2005). Shrimp production from this type of culture is relied on both the traditional low density method of wild shrimp gained by opening the gates and impounding its wild larvae and the natural productivity of the pond as feed for wild shrimp. Due to the demand of shrimp products from international market has increased during 1985-1988; however, the traditional shrimp culture was replaced by more productive practices either semi-intensive or intensive shrimp culture to serve global market. For the practice under semi-intensive shrimp culture requires pond enclosures, shrimp fry from hatchery with high stock density at 6-25 PL/m^2, manuring and fertilization, water exchange, usage of aerator, use of high nutritive feeds and usage of drugs and chemicals. For intensive shrimp culture is quite similar to semi-intensive but requires high financial, technical inputs, higher stocking density at 25-35 PL/m^2, better water exchange, drainage and removal of sludge (Szuster, 2003; Tookwinas, n.d.).

From the global demand on shrimp products and technology of either semi-intensive or intensive shrimp farming which has expanded significantly in the last two decades, shrimp farms has rapidly expanded to along the coastal provinces in the central, eastern, and southern part of Thailand in the last 2 decades. Its consequence has led Thailand become the world’s leading exporter for shrimp products continuously for several years (Manarungsan, 2005).

Since almost a half century, Chachoengsao province has experienced the extensive development of inland shrimp farming in the central plain (Braaten and Flaherty, 2000). Both of industrial and smallholder shrimp farms are wide spread in the province. There is not much declining in number of shrimp farms due to the high market prices of raw shrimp product (Fisheries Information Technology Center, 2014). Currently, more than 8,000 shrimp farms or more than 29,157 shrimp ponds obtained from digitizing by using Google Earth Map that released on January 13rd, 2011 are existing in Chanchoengsao province (Figure 3.3). Mix cultures between white shrimps and giant freshwater prawns are the most preferred option for small-scale shrimp farmers in the province.

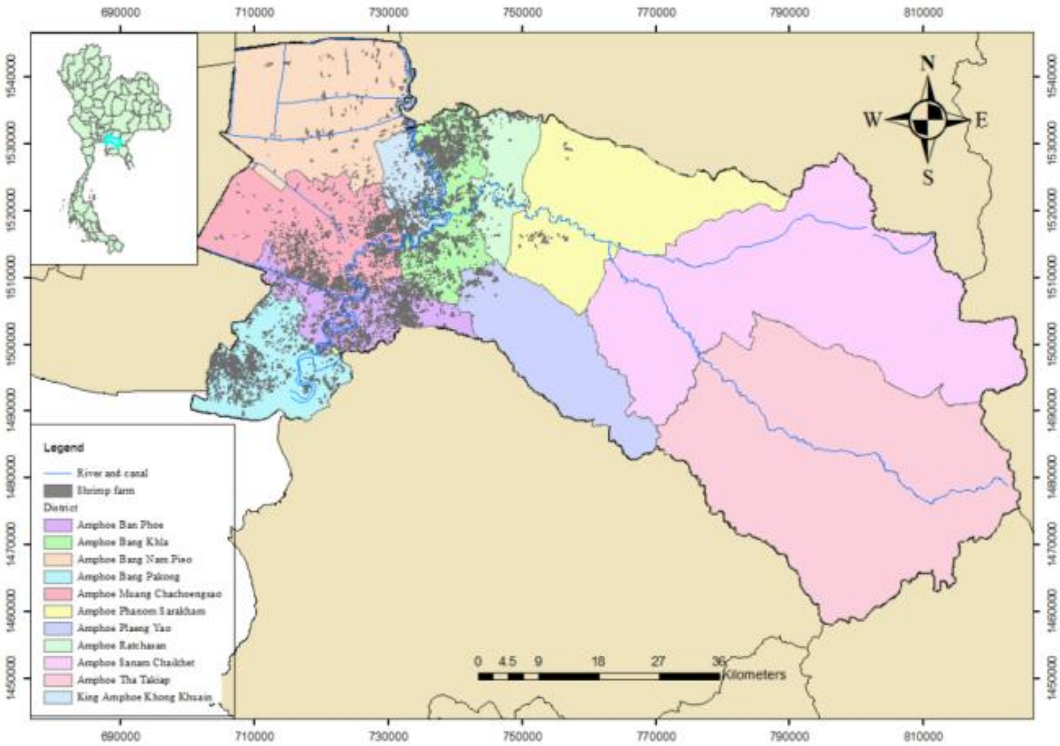

Figure 3.3 Map of study area with shrimp farms located in each district of Chachoengsao province

In term of economic loss and spatial extent, The Department of Fisheries, Thailand reported that 1,514 shrimp farmers in the province experienced extreme floods in 2011 which caused approximately 109 million Baht (3.41 million US$) of damages. A report by the Chachoengsao Disaster Prevention and Mitigation Office (October 10th, 2013) reveals that all shrimp ponds (totally 1,060 with an area of approximately 640 ha) were inundated. This flood disaster has overflown more than ninety percent of shrimp farms in the provinces (Figure 3.4). Damage from losses of shrimp stock due to the flash floods in 2013 was also estimated to be 11.88 million USD for three eastern provinces including the Chachoengsao province. The exact cost was; however, still uncertain since it was subject to the age of shrimp and current shrimp prices. Damage cost on shrimp farm may be higher than expected if harvesting is not yet carried out when shrimp attain the market size.

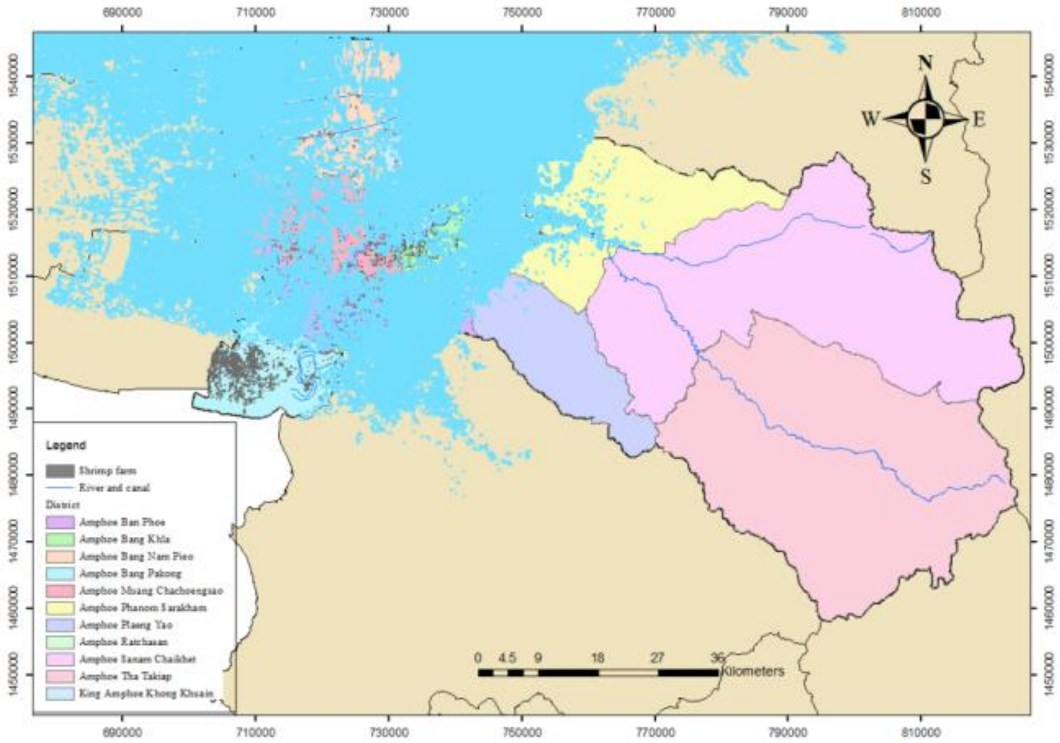

Figure 3.4 Overlaying shrimp farm map with flood extent as happened on October 30, 2011

Moreover, many million Baht per year given by Department of Fisheries to remedy shrimp farmers who affected by flooding was observed to occur in almost every year as shown in Table 3.1. A flood in 2011 was the worst flood to hit Thailand and also shrimp farms in the study area. Figure 3.5 illustrates the devastation caused by this flood.

Table 3.1 Impacts of floods to shrimp farming in Chachoengsao province during 2005-2011

Year	Flooding period	Number of shrimp farmers affected by floods	Number of shrimp areas lose from floods (rai)	Worth of damage (Million Baht)	Amount of financial assistance (Million Baht)
2005	Sep	98	315.7	-	0.55
2006	Sep-Nov	1,821	4,548	-	33.73
2007	-	-	-	-	-
2008	May-July	42	45	-	0.85
	Sep-Oct	347	453.5	-	6.16
2009	-	-	-	-	-
2010	-	-	-	-	-
2011	Sep-Nov	1514	5,509	105.89	56.7

Source: Department of Fisheries (2012)

Figure 3.5 Inundated shrimp farms in 2011 (photos were taken from Suratthani province in 2011)

3.1.4 Adaptation of shrimp farmer on flood event in Chachoengsao province

Since flooding is a cyclical event in Chachoengsao province, the shrimp farmers have developed their own practice of adaptations for responding to the impending flood event. These adaptations may include actions from group of shrimp farmers or individuals. All the adaptations are a consequence of responses to the floods based on their experience.

Currently, national and regional holistic plan and management scheme to combat flooding do not exist. Government actions mainly follow reactive actions. An example of a reactive action is to provide the disaster relief fund for the flood victims. The most probable reason for relying on reactive action is the lack of both precise and accurate flood forecasting and defined adaptation practice regulated for particular shrimp farming. Although the municipal governments have placed most emphasis on reactive actions, shrimp farmer itself has done their best responses for combating flood crisis. The action taken by shrimp farmer can be significant because its effectiveness of adaptation measure to prevent the damage of flood can induce replication by other shrimp farmers. Unfortunately, all action taken could not completely the loss from flood either putting the net around the pond or increase the height of shrimp pond by putting the sand bags and using excavator (Figure 3.6).

Figure 3.6 Action taken to prevent the damage from the worst flood in 2011

Cyclical floods also educate the shrimp farmers to have better flood response plans. Even though the majority of the shrimp farmers are small-scale farmer, but effort to prevent or reduce flood impacts is not limited only industry shrimp farms. Adaptation approaches for shrimp farmers depend on availability of technical and financial capacity to handle potential flood impacts.

3.2 Research framework

This section presents the research framework showing my approach for assessing and modeling vulnerability and adaptation of shrimp farms to extreme floods. The research framework also establishes the boundaries of my research within a broad literature on vulnerability, risk and adaptation assessment.

Based on my research problem formulation, the research aim is to explore a specific set of factors in term of its vulnerability to flooding by assessing adaptation measures in order to find the best option for reducing future flood vulnerability. Since the shrimp farms used for the case study is assumed to represent a wider shrimp farms in Thailand, the results of the research should have wider relevance. Hence, the suggested adaptation measure which gives the best net benefit will be used to formulate as a general framework for flood risk management in a wider context.

To assess the vulnerability and adaptation of shrimp farms to extreme floods for this study, the process of the research which is adopted from Adaptation Policy Framework from Downing (2012) can be divided into four main stages as follows: identification of vulnerability factors, assessment of current vulnerability for both physical vulnerability and social vulnerability, assessment of future vulnerability and adaptation, and economic analysis. The research process is summarized in Figure 3.7.

The methodology consists of identification of vulnerability indicators required for assessment of vulnerability to flood and adaptation measures to adapt against flood as the first task. Independent variables related to core element of vulnerability assessment whether exposures, sensitivities and adaptive capacities were identified for further assessment. The rational basis for defining indicators is provided in sector 3.3. Then, it is important to identify the vulnerability indicators which can be formed vulnerability baseline of present condition in order to assess the current vulnerability and future vulnerability with different scenarios as the second, third and fourth task, respectively. Details of the mapping current and future vulnerability were given in sector 3.4 and 3.5, respectively. For future vulnerability assessment, the estimation of damage costs based on the consequences obtained from different scenarios can be brought the interests from both government and shrimp farmers to put their effort for preventing the occurrence of flood as described in sector 3.6. The last task will be the development of adaptation strategies through public consultation meeting with shrimp farmers as details illustrated in sector 3.7.

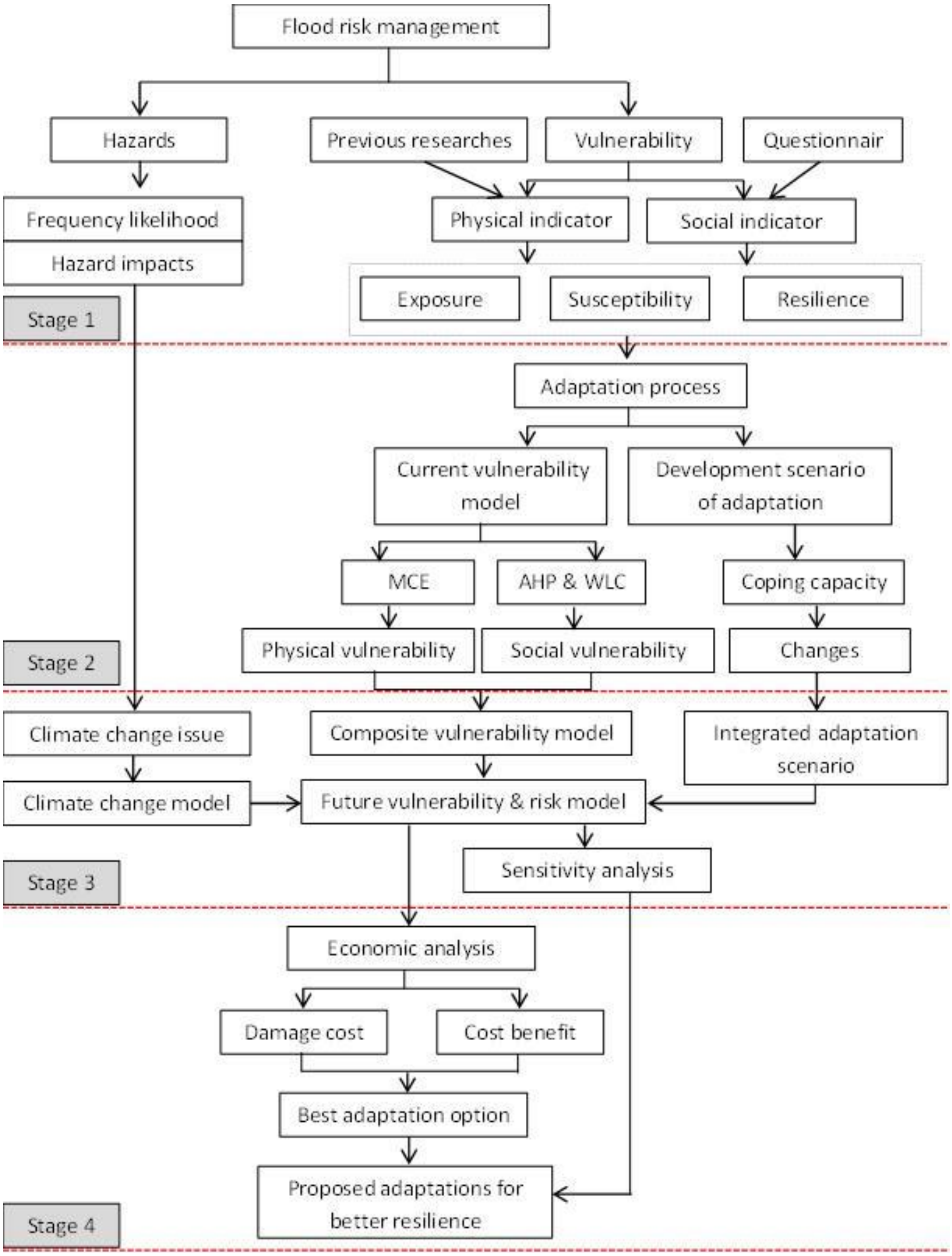

Figure 3.7 Purposed methodologies for the research

3.3 Collection and identification of vulnerability indicators

For the first stage, I mainly focused on identification of vulnerability indicators, and the preliminary vulnerability factors relevant to my case study. I also select some variables reflecting vulnerability indicators and other variables impacting to vulnerability indicators in the model. For defining vulnerability indicators, I conducted a literature review from existing published papers as well as government and academic reports. I also used a secondary analysis method to define vulnerability indicators from the literatures.

As the scope of the study focused on the impacts of floods on shrimp farming in Chochoengsao province, the relevant literature on this field are the main destination used to identify vulnerability indicators. Identifying vulnerability indicators and vulnerable groups of shrimp farmer either small-scale farmer or industrial farmer in Chachoengsao province by the judgment of expert based on available data and expert opinion can be form vulnerability baseline of present condition. These advised vulnerability indicators can also be used to project future vulnerability conditions of shrimp farms areas to floods. Selection of indicators based on four components; social, economic, environment and physical, from the study on literature was carried out based on theoretical comprehension with emphasis on the deductive research approach of Balica (2012). Understanding the cause of floods and their effects components of the system for shrimp production in Chachoengsao province as showed in Figure 3.8 was used to lead the recognition of the optimal indicators. Fundamental knowledge on flood occurrence and/ or previous research were taken into account to guide which vulnerability indicators are relevant to the study area. Moreover, participatory process involving with the stakeholder, communities and experts using questionnaire to avoid potential bias of identification of vulnerability indicators was implemented.

Selected vulnerability indicators can be divided into 3 main vulnerabilities groups; adaptive capacity, sensitivity and exposure. For the identification of adaptive capacity of shrimp farmer at the provincial, district and sub-district level was done by surveying and questionnaire. Units of measurement of each vulnerability indicator were defined. To link the functional relationship between indicator and vulnerability, hypothesized direction of relationship with vulnerability was demonstrated and established to confirm the main hypothesis of the study.

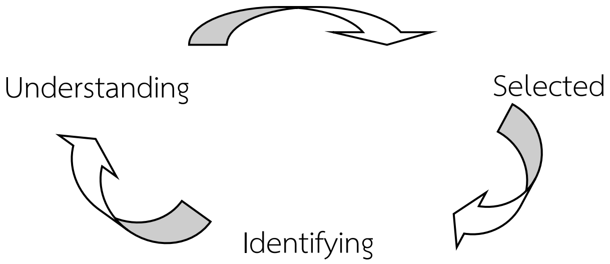

Figure 3.8 Deductive approach process

Source: Adopted from Balica (2012)

Even though selected vulnerability indicators; for instance, can be divided into 3 main vulnerabilities groups; adaptive capacity, sensitivity and exposure, but motivation for selecting of vulnerability indicators is form Unesco-IHE Institute for Water Education who provides the list of indicators used to assess flood vulnerability. Table 3.2 shows the overall indicators resulted from the consultation meeting among experts from several universities and academic institutes (Balica, 2012). These indicators are also available in the website of Unesco-IHE Institute for Water Education (http://unesco-ihe-fvi.org/). The table also reveals the relation of vulnerability components, indicators and factors for various spatial scales. However, the availability of data and the importance of indicators for certain study areas are main concerned for selection of the indicators. Therefore, the importance of selecting indicators is an actual. Flood vulnerability can be changed; for instance, from decreasing of the protection of nature areas and/or land use. While flood impacts may be reduced if rising flood risk awareness or increase the height of dike.

Table 3.2 Overall indicators and relationship between components, indicators and factors

Flood vulnerability	Overall indicators								
	Relationship between component and factors								
	Exposure			Susceptibility			Resilience		
		Abb	Geographic scale		Abb	Geographic scale		Abb	Geographic scale
Social Component	Population density	Pd	R,S,U	Past experience	PE	R,S,U	Warning system	WS	R,S,U
	Population in flood area	Pfa	R,S,U	Education (literacy rate)	Ed	R,S,U	Evacuation routes	ER	R,S,U
	Closeness to inundation area	Cia	R,S,U	Preparedness/Awareness	A/P	R,S,U	Institutional capacity	IC	R,S,U
	Population close to coastal	Pool	R,S,U	Child Mortality	Cm	R,S,U	Emergency service	ES	R,S,U
	Population under poverty	Pp	R,S,U	Communication penetration rate	CPR	R,S,U	Shelter	S	R,S,U
	% of urbanized area	%UA	R,S,U	Population with access to sanitation	PwaS	R,S,U			
	Rural population	Rpop	R,S	Rural population who access to WS	PwoWS	R,S			
	Cadastre survey	CS	R,S	Quality of water supply	QWS	S,U			
	Cultural heritage	CH	S,U	Quality of energy supply	QES	S,U			
	% of disable	%disable	U	Population growth	PG	S,U			
				Human health	HH	S,U			
				Human development index	HDI	S,U			
				Urban planning	UP	U			
Economic component	Land use	LU	R,S,U	Unemployment	UM	R,S,U	Investment in c. measure	Amin	R,S,U
	Proximity to river	PR	R,S,U	Income	I	R,S,U	Infrastructure management	FI	R,S,U
	Closeness to inudation area	Cia	R,S,U	Inequality	Ineq	R,S,U	Dams & storage capacity	ECR	R,S,U
	% of urbanized area	%UA	R,S	Yearly volume	Vyear	R,S,U	Flood insurance	FI	R,S,U
	Cadastre survey	CS	S,U	Life expectancy index	LEI	R,S,U	Economic recovery	ECR	R,S,U
				Urban growth	UG	S,U	Past experience	PE	S,U
				Child mortality	CM	S,U	Dikes/levees	DL	S,U
				Regional GDP/capita	GDP	S			
				Urban planning	UP	U			
Environmental component	Ground WL	GWL	R,S,U	Natural reservations	NR	R,S,U	Recovery time to floods	RTF	R,S,U
	Land use	LU	R,S,U	Years of sustaining health life	YSHL	R,S,U	Environmental concern	EC	R,S,U
	Over used area	DUA	R,S,U	Quality of infrastructure	QI	R,S,U			
	Degrated area	DA	R,S,U	Human health	HH	S,U			
	Unpopulated land area	Unpop	R,S	Urban growth	UG	S,U			
	Types of vegetation	TV	R,S	Child Mortality	CM	S,U			
	% of urbanized area	%UA	R,S	Rainfall	Rainfall				
	Forest change rate	FCR	R	Evaporation	Ev				
Physical component	Topography (slope)	T	R,S,U	Building codes	Bo	U	Dam & storage cpacity	DSC	R,S,U
	Heavy rainfall	HR	R,S,U	Frequency of occurance	FO	R,S,U	Roads	R	R,S,U
	Flood duration	FD	R,S,U				Dikes/Levees	DL	S,U
	Return period	RP	R,S,U						
	Proximity to river	PR	R,S,U						
	Soil Moisture	SM	R,S,U						
	Evaporation rate	Ev	R,S,U						
	River discharge	RD	R,S,U						
	Flow velocity	FV	S,U						
	Storm surge	SS	S,U						
	Rainfall	Rainfall	S,U						
	Flood water depth	FWD	S,U						
	Sedimentation load	SL	S,U						
	Yearly volume	Vyear	S,U						

Remark: R is river basin scale, S is sub-catchment scale and U is urban area scale.

In order to ensure that relevant indicators available for assessing the vulnerability, the sourcing of the relevant literature was carried out as shown in Table 3.3. Primary data; in addition, was also collected for assessing the vulnerability as illustrated in Table 3.4. These data were not only used for selecting the vulnerability indicators but also for flood vulnerability assessment. Here below are the details of collection data related to vulnerability indicator.

3.3.1 Secondary data collection

All relevant data such as frequency of extreme events, changing climate, records on the affected shrimp farm and shrimp farming practices for example over the study area since the past 5 decades were collected and reviewed. Types of the data and its sources collected are showed in Table 3.3.

Table 3.3 Type and source of secondary data collected for selecting vulnerability

Type of data	Source of data
1. Spatial information i.e. digitized aquaculture area, aerial image and satellite image	Department of Fisheries, Department of Land Development and GISTDA
2. Water quality monitoring of Bangpakong and important branch canals	Regional Environmental Office 13, Institutes and agencies
3. Physical and biological impacts of climate change on aquaculture	Journals and accessible sources
4. Evidence of impacts of climate change on aquaculture in other regions	Journals and accessible sources
5. Current evidence of impacts caused by climate change	Chachoengsao Fisheries Provincial Office, Chachoengsao Coastal Fisheries Research and Development Center
6. Adaptation actions by shrimp farmers	Chachoengsao Fisheries Provincial Office, Chachoengsao Coastal Fisheries Research and Development Center and Institutes
7. Adaptation, mitigation and guidelines to prevent loss of aquaculture production	Journals and accessible sources
8. Current policy regarding to climate change adaptation	Related and responsible governments
9. Models used to forecast the impact of climate change on aquaculture	Journals and accessible sources
10. Weather record in the past decade	**Thai** Meteorological Department
11. Fisheries statistic records	Department of Fisheries

3.3.2 Primary data collection

The needed relevant primary data to be used for developing the model was collected. This data; for example, is also related to the past flood experience which is one of the set of indicators suggested by Balica (2012). The type of primary data and method of collection are described in Table 3.4.

Table 3.4 Type and method of primary collected for selecting vulnerability

Type of data	Method of collection
1. The extent of aquaculture areas affected by climate change	Site survey and interview by using questionnaire survey and in-depth interview
2. Awareness of latest prediction of climate change	Questionnaire, interview and site survey
3. Practical adaptation of aquaculture farmers for those impacts of climate change	Questionnaire, interview
4. Existing impact of climate change	In-depth interview with experts

In addition, verification accuracy of the collected data was carried out by different two ways ; cooperation with the local competent authority in Chachoengsao province particularly Chachoengsao Fisheries Provincial Office and the investigation on site by using Geographic Position System (GPS) receiver at the selected areas

3.4 Current vulnerability scenario

The main goal in vulnerability modeling in this research was to find the current flood vulnerability situation of the study area. The most effective of the vulnerability assessment can be found by comparing the different gaps between the result of vulnerability mapping and the extended of inundation area impact by flood in 2011 and 2012. The assessment of the flood vulnerability of shrimp farms in Chachoengsao Province which was adopted from the Adaptation Policy Framework by Downing (2012) was focused on assessing the current vulnerability of shrimp farms to flood occurrence by using typical hydrological, physical and environmental components as the primary data. Geo-environmental characteristics have been applied to assess the flood-vulnerable areas of this study.

Not only focused on hydrological, physical and environmental components, but also social component is the main objectives for the study of the current vulnerability scenarios. The outcome from mapping vulnerability map based on typical hydrological, physical and environmental components could imply the likelihood of vulnerability and risk of the study area which is considered as the flood prone area. The physical vulnerability map which is considered as the first data set of current vulnerability assessment could aggregate with the social vulnerability which is considered as the second data set. To obtain the current vulnerability scenario of the study, the methodology on this part can be divided into two main sets as follows:

3.4.1 Physical vulnerability

Baseline data of sensitivity vulnerability component such as drainage density, lineament density, lithology (soil type), rainfall, slope, temperature and land cover or land use are keys to improve the understanding vulnerability on geo-physical environments of the area to be affected by extreme flood events under changing climate and of the rate of change in which those impacts appear (Michael, 2009). In particular, flood event occurred from climate variables during the last 7 years at Chachoengsao province was used to delineate flooded area in order to compare with the consequence of physical vulnerability assessment. For the delineating non-flooded areas, it can be served as a temporary shelter for the nearby settlements (Sanyal and Lu, 2005). This map is necessary for identifying the settlement considered as shrimp farms where are highly vulnerable to flooding.

Subsequence steps used for the assessment of current physical vulnerability were implemented by the conjunction of the climatic hazards, socio-economic conditions and the current adaptation baseline of shrimp farmers. The implementation of combining and weighing the different vulnerability factors and components was carried out by using Spatial Muti-Criteria Evaluation in a GIS based on the Analytical

Hierarchical Process (AHP), which was developed by Saaty (1980), for the analysis of current vulnerability and finding the flood vulnerability areas.

To make spatial multi-criteria analysis of the physical vulnerability assessment, the input layers of selected vulnerability indicators need to be implemented as following:

3.4.1.1 Classification and standardization of criteria

Input layers were standardized and classified from their original values to the value range of 0-1 based on the decision of expert and the results from survey literatures.

3.4.1.2 Weighing criteria

After selecting the appropriate vulnerability indicators and standardization, the hierarchical structure weights to represent a problem and then develop priorities for alternatives was done based on the judgment of an expert. Pair-wise comparison for each element of the hierarchy structure to all the associated elements are compared as illustrated in Figure 3.9:

$$A = \begin{bmatrix} 1 & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & 1 \end{bmatrix}$$

Figure 3.9 Example of comparison pairwise matrix (Vahidnia, 2008).

3.4.1.3 Estimate the relative weights

Eigenvalue method was used to calculate the relative weights of elements in each pairwise comparison matrix. The relative weight (W) of matrix A is obtained from following equation:

$$(A - \lambda_{max} I) \times W = 0$$

Where λ_{max} = the biggest eigenvalue of matrix A, *I* = matrix

3.4.1.4 Check the consistency

To ensure that the judgments of decision maker on weighting are consistent, check the consistency (CR) will be implemented as equation below. Generally, if CR is less than 0.1, it means that the judgments are consistent and so the derived weight can be used.

$$CR = \lambda_{max} - n/(n-1)/RI$$

where λ is the maximum eigenvalue of the matrix, n is the number of elements in the matrix, and the RI (random index) values were adopted from Saaty (1980), as shown in the table below. The table shows the average consistency index, which was randomly generated (i.e., inconsistent) using the pairwise comparison matrices.

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

3.4.1.5 Obtain the overall rating

Rating used to give the ranges of flood vulnerability within each index was assigned to each class according to the order of the influence of the class to flood occurrence. The relative weights of rating range were adopted from below equation

$$W_i^s = \sum_{j=1}^{j=m} w_{ij}^s w_j^a, \quad i = 1, 2, \ldots, n$$

Where W_i^s = total weight of site i,

w_{ij}^s = weight of alternative (site) i associated layer to attribute (map layer) j,

w_j^a = weight of attribute j,

m = number of attribute

n = number of site

3.4.1.6 Mapping the standardized measure of weight

Current physical vulnerability map of the study area according to assigned weight ratio and classification was produced in ArcGIS® software version 10 by ESRI. Map was made using a grid cell size of 100 meters on each side. Vulnerability map can be created by each criterion and then was aggregated into the vulnerability map of the study area. Flood vulnerability index (FVI) equation linked the value of all indicators to flood vulnerability components and factors for this study as illustrated below was used to process and map for physical vulnerability to floods. This equation can be used to aggregate with the social vulnerability assessment which will be explained in the next section.

Flood Vulnerability Index (FVI) = weighted and rating summation from three subcomponents of vulnerability; exposure, sensitivity and adaptation.

or illustrate as following equation $FVI = E * S / R$

where E is the set of exposure indicators, S is the set of sensitivity indicators and R is the set of resilience indicators

3.4.1.7 Assessment of the flood vulnerable area

Overlaid raster layers consisting of a gridded array of cells in ESRI ArcGIS and a multicriteria evaluation using the FVI equation were used to determine the area vulnerable to flooding. The factors were weighted and rated according to their relative importance using the spatial analysis tool in ArcGIS® software version 10 by ESRI. Then, the flood-vulnerable area was identified. Flood vulnerability was divided into 5 categories based on the vulnerability potential in the event of flooding (Table 3.5) according to percentile thresholds (i.e., 0-20%, 20-40%, 40-60%, 60-80% and 80-100%). The locations of shrimp farms in Chachoengsao Province were overlaid with the flood-vulnerable area to identify areas where shrimp farms are susceptible to flooding and where adaptation practices should be prepared in advance. Shrimp farms that are located in the flood-vulnerable areas are likely to be severely damaged.

Table 3.5 Flood vulnerability categories/designations.

Vulnerability category	FVI range	Description
Very low	0 - 0.2	The area features a very low vulnerability to floods. Shrimp farms or residential properties located in this area are safe from floods, even in the event of a typhoon.
Low	>0.2 - 0.4	The area sometimes experiences floods. Few shrimp farms in this area are affected by floods during the high rainfall caused by typhoons.
Moderate	>0.4 - 0.6	The area is moderately vulnerable to floods. Uncertain amounts of rainfall induce a moderate potential for shrimp farming losses.
High	>0.6 - 0.8	The area is highly vulnerable to floods. A large amount of rainfall over a short period creates a high potential for shrimp farming losses.
Very high	>0.8 - 1	The area is very highly vulnerable to floods. A large amount of rainfall during a short period causes a very high potential for shrimp farming losses and/or extreme economic losses.

Source: Modified from Balica et al. (2013) and Devkota (2013).

3.4.2 Social vulnerability

The methodology for assessment the vulnerability and adaptation of shrimp farm to extreme flood occurrence for this study can be divided into five tasks (4 main components) which adopted Adaptation Policy Framework from Downing (2012) as described in research framework. For this part of methodology, adaptation practices undertaken to cope with flood occurred in the past were also taken into account for assessing the current vulnerability to flood. Then, the construction of social vulnerability index was carried out for understanding current socio-economic situation of the shrimp farmers in the study area. The socio-economic conditions of the shrimp farmers would imply the reason of selecting adaptive practices used to prevent the loss from flood devastation. The **details** of methodology for study on adaptation practices that have been undertaken by shrimp farmer could be shown as follows.

3.4.2.1 Current adaptation practices

Vulnerability assessment is the one of method to identify adaptation strategies that is feasible and practical in communities on risks and hazards. Cochrane (2009) addressed that options to increase resilience and adaptability through improved aquaculture management include the adoption as standard practice of adaptive and precautionary management. Stakeholder capacity and experiences are needed to take into account for assessing the adaptation. This study also assessed the adaptation practices and capable of adaptation practices of shrimp farmers in Chachoengsao province to flood occurred in the last 5 years. Primary data on adaptation was collected by using questionnaire to interview shrimp farmers, who were the victim from the worst flood in 2011. Based on the record of Chachoengsao Provincial Fisheries Office about the financial relief fund given to shrimp farmer after floods in 2011, it revealed that 812 shrimp farmers from 9 districts of total 11 districts at Chachoengsao were affected by worst flood in 2011. Total number of victims in each district was used to calculate the sample size by using Taro Yamane’s formula (Yamane, 1967) at the confidence level 95%. A total sample of 109 from 6 districts as details showed in the Table 3.6 were interviewed during 31 January until 8 February 2013 and chosen to replace the sample from nearby districts where victims have changed their occupation from shrimp farming to others such as Plaeng Yao, Phanom Sarakham and Sanam Chai Khet. The other reason but not least important for this selection is that number of victims from these districts were very few and could not be able to find these victims for interviewing purpose. It was reason that the total number of interviewed victim was less than the expected victims that need to be interviewed. Therefore, the studies on these districts with different number of victim according to the result of calculation using Yamane's formula helped to clarify the impacts of floods on shrimp farming, particularly adaptation practices and capability to cope with flood under the same natural disaster conditions.

Table 3.6 Number of shrimp farmer who victim from worst flood in 2011 and number of sample for interviewing in each district of Chachoengsao province

District	Number of shrimp farmer who were victims	Number of sample calculated in accordance with Yamane's formula	Number of interviewed victim for this study
Bang Khla	258	26	26
Ratchasan	23	16	3
Khlong Khuean	69	22	22
Muang	14	13	5
Plaeng Yao	1	1	0
Ban Pho	418	43	50
Bang Nam Priao	26	14	3
Phanom Sarakham	2	2	0
Sanam Chai Khet	1	1	0
Total	812	138	109

Remark: Shrimp farmers in Ban Sang, who were victim, were also interviewed in order to replace the victims in Ratchasan district because they are now changed their occupation from shrimp farming to paddy field after worst flood in 2011.

According to data analysis, an analysis of qualitative primary data obtained from the survey was done by using content analysis in which the data were broken down into meaningful themes and summarized to supplement important information with respect to the objective of the study. Quantitative data analysis was based on description statistic especially percentage. Inferential analysis involved chi-square test at $p < 0.05$ level of significant and corrected Rao-Scott chi-square (χc2) were used to determine association between variables for multiple response answers (Lavassani, 2009).

3.4.2.2 Social vulnerability of shrimp farms to floods

The current (baseline) adaptive capacity in relation to floods, as determined from 2011-2012, was evaluated for shrimp farmers in the study area. The socio-economic status of shrimp farmers was examined to determine the adaptive capacity at the district level in Chachoengsao province. A questionnaire survey was conducted to identify the adaptive capacity of shrimp farmers who had encountered previous flooding problems. The questionnaire consisted of six sections, including two sections for acquiring general information, while the rest was designed to record specific activities and practices for determination of the adaptive capacity (including the socio-economic characteristics of the shrimp farmers, past flood experience, the adopted practices and their effectiveness, and adaptive strategies to address flooding in the next 3 years). The questionnaires shown in Appendix A were designed to evaluate 20 indicators, as suggested by Balica (2012). The selected indicators represent four components (social, economic, environment, and physical) and cover all of the factors relevant to vulnerability; the exposure, sensitivity and adaptive capacity used in the computation are summarized in Table 3.7. The total sample site 109 of 812 total shrimp farms who were flood victims were interviewed face-to-face during January and February 2013.

Social vulnerability was evaluated based on the information and indicators acquired from the questionnaire. Then, social vulnerability was integrated with physical vulnerability into the composite vulnerability assessment. All indicators were normalized using minimum-maximum normalization, ranging from 0 to 1 (0 = very low vulnerability to floods, and 1 = very high vulnerability to floods) as illustrated in Table 3.5. Reclassification of social variables into five impact categories was then carried out according to the physical vulnerability assessment. As suggested by Balica (2012), the consequences of the functional relationships and sources of indicators were adopted, as summarized in Table 3.7. The standard score for every variable was then determined through normalization of the indicators associated with the functional relationship. Equation (1) was used when the variables showed a positive functional relationship with vulnerability; when the variables showed a negative relationship with vulnerability, equation (2) was adopted.

$$X_{ij} = (x_{ij} - \min x_i) \,/\, (max\, x_i - \min x_i) \qquad (1)$$

$$Y_{ij} = (max\, x_i - x_{ij}) \,/\, (max\, x_i - \min x_i) \qquad (2)$$

where X_{ij} and Y_{ij} are normalized values of social vulnerability indicators (variables); x_{ij} is the original score of the variable number ordered i^{th} in the analysis and the unit number ordered n^{th}; max x_i is the highest variable score; and min xi is the lowest variable score.

After normalization, the respective scores for all of the indicators of the social vulnerability indices were calculated using equal weights, due to the aforementioned lack of a clear determination of the importance of all social indicators (see Equation (3). Finally, the vulnerability indices were used to rank the vulnerability of each district of Chachoengsao province and were interpreted to obtain the vulnerability area map to determine which districts represent potential hotspots of social vulnerability.

$$Vulnerabilitiy = \frac{\left(\Sigma_j x_{ij} + \Sigma_j y_{ij}\right)}{k} \qquad (3)$$

Table 3.7 Indicators of vulnerability indices and functional relationships with vulnerability.

Factor of vulnerability	Component	Indicator	Proxy variable	Source of indicator	Functional relationship with vulnerability
Exposure	Social component	Shrimp farmer population density (Pd)	No. shrimp farmers/km^2	There is significant exposure to a given hazard if the population is concerned	+
		% of small shrimp farmers (SM)	%	% of shrimp farm of less than 50 rai (8 ha)	+
		Population in poverty (Pp)	%	Percentage of shrimp farmers falling below the poverty line	+
		Forest change rate (FCR)	%	% change from forest areas to land areas	+
Susceptibility	Social component	Government-designated floodway (DFF)	%	% of shrimp farmers affected by floodways designated by the government of Klong Rabhiphat in the last 2 years	+
		Runoff from a nearby province (RF)	Year	Year in which a flood caused by runoff from a nearby province occurred in the last 2 years	+
		Past experience (PE)	%	% of shrimp farmers who have been affected by flood events in the last 2 years	-
		Education (Ed)	%	% of shrimp farmers who graduated with at least a bachelor’s degree	-
		Preparedness/awareness (A/P)	%	% of shrimp farmers who prepared for/were aware of floods	-
		Communication penetration rate (CPR)	%	% of shrimp farms with a source of information	-
	Economic	Debt to income (DI)	ratio	DI = Monthly debt payment/gross monthly income	+
		Wealth (saving status) (SS)	%	% of shrimp farmers who have monetary savings	-
		Unemployment (UM)	%	(Number of shrimp farmers who do not have another occupation	+

				divided by the total number of shrimp farmers)*100	
		Life expectancy for shrimp farming (LEI)	-	LEI = (LE-20)/(82.3-20), where the number of years of life remaining at a given age	-
	Environmental	Natural reservation (NR)	%	% of natural reservation areas in the river basin	-
	Physical	Frequency of occurrence (FO)	Year	Years between floods (every time in the last 2 years, high vulnerability)	+
Resilience	Social component	Warning system (WS)	%	For no WS, the value is 1; if a WS exists, then the value is 0	-
		Emergency service (ES)	%	Percentage of emergency services available	-
	Economic	Recovery time after floods (RIF)	%	Percentage of shrimp farmers who could recover their shrimp farm in less than 1 month	-
		Flood insurance (FI)	-	The value of flood insurance; if none, then a 1 is scored	-

Remarks: (+) positive relationship with vulnerability, (-) negative relationship with vulnerability

Source: Modified from Cutter (2003) and Balica (2012).

3.4.3 Integration of physical and social vulnerability into a composite vulnerability map

The composite total vulnerability in relation to the current adaptive capacity was determined through weighted linear combination (WLC) of the physical and social vulnerability maps to activate the conceptual model within a GIS framework (Dewan, 2013). The approach of equal weighting was adopted from Cutter (2003) and implemented in this study. The severity of total vulnerability, ranging from 0 to 1, was then determined through ArcGIS spatial analysis data and was classified into five impact categories (very low, low, medium, high and very high) to estimate vulnerability.

3.5 Future vulnerability scenario

To establishment the adaptation strategies, the development a more qualitative understanding of the drivers of possible future vulnerability is necessary due to its dynamic and even policy on floodway. Technique to be assessed the future vulnerability which included cross-impact matrices from future exposure of climate trends or variations and different characteristics of adaptive capacity will be considered. Outputs of this assessment are qualitative description of the present structure of socio-economic vulnerability, future vulnerabilities and a revised set of vulnerability indicators included future scenario based on the future exposures and adaptive capacities and responses of shrimp farmer (Downing, 2012).

To assess the future vulnerability scenario, results from the current vulnerability assessment was used as the baseline for mapping vulnerable areas of shrimp farms to floods. There are two additional inputs required for future vulnerability assessment. The following points explain additional data in analyzing the future vulnerable area of shrimp farms to floods.

3.5.1 Climate change model

Additionally, climate projections and future flood vulnerability maps were taken into consideration in this assessment. The results of climate projection over the study area carried out by relevant researches were adopted for future vulnerability assessment. Worst case scenario of extreme amount of rainfall will also be used to assess future vulnerability. For adaptive capacities, the ecosystem approaches to aquaculture (EAA) would be applied to adopt in increasing the resilience of aquaculture production system and integrating aquaculture with other sector that share and affect common resource (Cochrane, 2009). To bring about adaptive measures of shrimp farms with an ecosystem perspective, the equation below would be interested to adopt for this study. FVI values for each component (social, economic, environmental and physical) can be summed up to aggregate and combine into an overall vulnerability for future assessment as illustrated in equation below:

$$\text{FVI}=\frac{\left[\left(\frac{E*S}{R}\right)\text{social}+\left(\frac{E*S}{R}\right)\text{economic}+\left(\frac{E*S}{R}\right)\text{environment}+\left(\frac{E*S}{R}\right)\text{physical}\right]}{4}$$

where FVI is referred to flood vulnerability index; E is referred to the exposure; S is referred to sensitivity and R is referred to resilience

The steps to map the vulnerability area in different future scenarios will repeat the same methodology mentioned in section 3.4 of accessing current vulnerability.

3.5.2 Development scenario of adaptation

The creation for second data set consists of the consequence from estimating a system's ability or shrimp farmer's ability to modify vulnerable conditions to flood occurrence by reducing social vulnerability level. To illustrate the result of flood vulnerability when increasing the adaptive capacity, the analysis has combined two data sets using GIS mapping technique. This part of research discussed the results of social vulnerability and composite vulnerability using analytical hierarchy process (AHP) and weighted linear combination (WLC).

The indicators listed in the Table 3.7 were subjected to evaluation of their ability to reduce vulnerability. However, indicators that are well represented and could measure vulnerability reduction were identified during the site survey. These indicators were confirmed by village leaders who were also shrimp farmers through in-depth interviews about the building of their adaptive capacity. Because the indicators are consistent with the modified system that could reduce flood vulnerability suggested by Luers et al. (2003) ("a shift in the well-being function that decreases the exposure and sensitivity"), this system was used to project the vulnerability map to represent mechanisms of reducing vulnerability after improving the socio-economic status. The adaptive capacity of shrimp farmers to adapt themselves would therefore be represented using Equation (4), adopted from Luers et al. (2003), as shown below.

$$A = V\,(existing\ conditions) - V\,(modified\ conditions) \tag{4}$$

where A is the adaptive capacity, and V is vulnerability.

Another modified system suggested by Luers et al. (2003), which involves a modification of the system's adaptive practices to cope with the impact, was subjected to testing of its relationship with the socio-economic characteristics of shrimp farmers. The Pearson Chi-square test was then applied using the Statistical Package and Service Solution (SPSS® version 22). This test provided initial evidence regarding the linkage between the current adaptive capacity, before a shift in the well-being of the shrimp farmers and the implementation of structural techniques either increasing the height of dikes or placing nets around shrimp ponds. The null hypothesis (H_0) was formulated as "there is no relationship between the socio-economic characteristics of shrimp farmers and the decision to employ structural approaches for adaptation", and the alternative hypothesis (H_1) assumed that "there is a relationship between the socio-economic characteristics of shrimp farmers and the decision to employ structural approaches for adaptation techniques". It should be noted that this study did not emphasize an examination of the relationship of socio-economic characteristics with the non-structural measures implemented by shrimp farmers because the structural measures to prevent flood damage were the first set of measures revealed by shrimp farmers.

3.5.3 Risk mapping

The concept of risk as a product of hazard and vulnerability has been extended to include exposure and climate change adaptation (Macchi, 2014). Flood risk map was developed using equation (5). Potential damage which is referred to as vulnerability map is based on integration of physical and socioeconomic which is resulted from the step explained in section 3.5.1 and 3.5.2. Shrimp ponds obtained from digitizing by using Google Earth Map that released on January 13rd, 2011 was also used to overlay with the flood risk map.

$$\text{Flood risk} = \text{Probability of the flood event (hazard)} \times \text{Potential damages (vulnerability)} \quad (5)$$

Parry (2007) defined hazard as the potential or probability of occurrence of natural event that may cause loss of life as well as damage and loss to property, infrastructure, ecosystem, and environmental resources. To identify hazards, a review of historic flood events observed between 2005 and 2013 is used for determination of hazard scores (Forte, 2005). Based on the previous flood events, chance of flood occurrence is likely to happen annually. The hazard scores of each district; therefore, were measured as to the likelihood of flood occurrence with ratings from one (1), three (3) and five (5) (Table 3.8) where one, three and five referred to the rating of possible, likely and very highly likely to flood, respectively.

Table 3.8 Correspondence between number of past floods events during 2005-2013 of each district and the historical flood hazard level

Number of past flood events in 2005-2013	District	Flood event (time/year)	Annual probability	Historical flood hazard	Score of livelihood
>4	Ban Pho, Bang Khla, Khlong Khuean, Muang, Ratchasan, Bang Nam Priao, Plaeng Yao, and Panom Sarakam	1-in-2	0.5	Very highly likely	5
>1 to ≤4	Tha Takiap, Bangpakong,	1-in-5	0.2	Likely	3
≤ 1	Sanam Chaikhet	1-in-8	0.125	Possible	1

Remark: There is no shrimp farm in Sanam Chikhet and Tha Takiap district

3.6 Economic analysis

Questionnaire survey has been applied for developing several key parts of the method such as estimating the damage cost, identifying the flood mitigation measure and identifying socioeconomic conditions of shrimp farmers. We use a future flood vulnerable area which their detail was integrated with hazard to form risk map to calculate expected annual damage in with and without proposed flood mitigation measures. The effectiveness of each measure and its cost were then evaluated in a cost-benefit analysis (CBA) under future flood vulnerable scenario.

3.6.1 Damage cost calculation

The expected damage cost on shrimp farming sector was estimated by using equation (6) which is based on an approach presented by Balica (2012) and Vorogushyn et al. (2012). It requires two main accountable inputs: (1) a flood risk map produced by using GIS to determine shrimp farm areas that are likely to be inundated, and (2) results from questionnaire survey on adaptation measures undertaken to cope with the last flood events and socio-economic condition of the victims.

$$ED=MV\times A\sum_{m=1}^{12} PM_m\times DI_m\times Y \qquad (6)$$

Where ED is an estimated damage cost (USD year^{-1}), MV is market value (USD ha^{-1}), A is affected area (ha) or shrimp farms that likely to be inundated by flood resulted from flood risk map, PM_m is probability of flooding for a certain month each year (year^{-1}), DI_m is damage impact on crops for month (%), and Y is yield per unit area.

There is also unaccountable information that needs to be assumed for the estimation of the flood damage cost. Information from available academic publication and statistical analysis were used in this case. For instance, the average prices for Thai shrimp raw material that was recently hit a new high level since the outbreak of early mortality syndrome (EMS) in 2012 until March 2014 was used as the market value to calculate the damage costs. One of the most important things that can differentiate the damage cost is the age of shrimp. Damages from flood incurred for shrimps that have not attained the market size are much lower than that of the market size. Two flood damage cost categories showing as maximum and minimum damage costs; therefore, were used to distinguish the potential damage costs. Estimated maximum damage cost is happened when market-size shrimps were flooded out with one hundred percent of damage on shrimp production (Muralidhar, 2010). Meanwhile, the calculation of the minimum damage cost was done under an assumption that a flood has started to overflow shrimp ponds on the first day after releasing shrimp fries. As hundred percent of damage on shrimp production is assumed, then calculation of damage cost in different probabilities of inundation depth is not taken into account. Summary of the accountable and unaccountable data used for the calculation of the damage costs was illustrated in Table 3.9.

Table 3.9 Accountable and unaccountable data used for the calculation of damage costs.

Data	Value and description	Source
Accountable data		
- Affected area	Four risk levels for shrimp farms areas to flood resulted from the flood risk mapping	Flood risk map
- Market value (minimum)	Price of shrimp fry obtained from questionnaire survey (Pacific white shrimp fry price is equal to 0.12 Baht or 0.0037 USD, while giant freshwater prawn fry price is equal to 0.29 Baht or 0.009 USD) was used as market value to estimate the minimum damage cost.	Questionnaire survey
- Yield	Average survival rate at 60% was also used to estimate the yield per pond size 1 rai (0.16 ha) when shrimp stocking density ratio between Pacific white shrimp and giant freshwater prawn is 50,000:6,000	Questionnaire survey
- Duration of flood (month)	Based on two main reasons: 1) past flood experience was occurred once a year and 2) duration of inundation is not relevant since shrimps can escaped when shrimp pond was overflown by flood. Therefore, duration of flood is assumed for one month	Questionnaire survey
Unaccountable data		
- Market value (maximum)	Shrimp price during the outbreak of early mortality syndrome (EMS) revealed that Pacific white shrimp price was 280 Baht or 8.75 USD/60 pieces per	Department of Fisheries

	kilogram, while giant freshwater prawn price was 400 Baht or 12.5 USD/50 pieces	
- % of damage impact	Hundred percent when cultured shrimp were flooded out	Muralidhar *et al.* 2010

Table above shows that questionnaire survey is main method to gain the accountable data for analysis of the economic. By using the Taro Yamane's formula (1967) with a confidence level of 95% to calculate the sample size, a total of 109 shrimp farmers, who were flood victims, from 6 districts (Bang Khla, Ratchasan, Khlong Khuean, Ban Pho, Bang Nam Priao, and Muang) were selected for interviews during January 31st to February 8th, 2013. The questionnaire covered the following topics: general information of shrimp farmer; experiences on the past flood; measures used for controlling the past floods; costs for construction of structural flood measures; selling price of raw shrimp in different situation of with and without impact by floods; willingness-to-pay for flood protection; and their preference on flood protection and adaptation measures. During the survey, numbers of adaptation options as implemented by shrimp farmers for reduction of the flood damages were identified. These include both structural and non-structure flood control measures. These measures were used to determine the relative costs and benefits base on the methodology as presented in the next section.

3.6.2 Cost and benefit analysis

Cost in term of flood management refers to expenses used to increase safety against flooding or decrease expected flood damages. Benefits in this economic analysis are measured as damages avoided (equation 7) resulted from investment in flood control measures. In this study, avoided damage costs are defined as the product of the avoided damage costs times the effectiveness of each structural flood control measure expected to be employed by shrimp farmers. Benefit/cost ratio (B/C ratio) is determined by examining the ratio of the present value of benefits to the present value of costs as shown in Equation 8. Meanwhile, the net present value (NPV) comparing the present value of cost streams with the associated present value of benefit streams is estimated by using equation 9.

Benefit from flood measure

=avoided flood damage

= flood damage without mitigation - flood damage with mitigation (7)

$$\text{B/C ratio} = \sum_{t=1}^{T} \frac{(B_t)}{(1+r)^t} \Big/ \sum_{t=1}^{T} \frac{(C_t)}{(1+r)^t} \qquad (8)$$

$$\text{NPV}= \sum_{t=1}^{T} \frac{(B_t-C_t)}{(1+r)^t} \qquad (9)$$

Where B_t is the benefit of a flood risk management strategy or “the avoided flood damage” in year t, C_t represents the cost, r is the discount rate, and t is the year in which r is realized.

In order to compare future benefits to costs of each flood control measure, a discount rate over the life-time of the proposed measures is used to estimate the net present value of the benefits. A positive NPV, thus, indicates that the sum of the discounted benefits exceeds the sum of the discounted costs over the lifetime. It is important to note that tangibles from direct damages (e.g. loss of paddle wheel motor) and indirect damages (e.g. increase transportation costs for harvested shrimp due to roads damage) as well as intangible damages (e.g. biodiversity losses) are not taken into account for this economic analysis.

Various types of costs are included in the estimation including: cost of initial investment or construction cost and the costs of annual maintenance over the life-time of a structural flood control measures. To identify the cost of adaptation measures, not only structural flood control measures but also non-structural flood control measures are used to determine the costs for protecting the shrimp ponds from adverse impacts of flooding. Since the majority of shrimp farmers claimed shrimp farming as their principle occupation for their whole life or for the next 50 years, a projected life of 50 years is assumed when shrimp farmers plan to prevent flood damages by applying only structural flood control measures. To estimate the costs for initial investment and maintenance costs, information as shown in Table 3.10 was used. The information was obtained from in-depth discussion with the community leaders who are themselves shrimp farmers at Ban Pho and Bang Khla district during the survey.

Table 3.10 Factors used for calculating the costs of each measure.

Factors	Value and description	Sources
Costs for initial investment		
- Dike height increase	- This cost was estimated from employment of external excavator for 2 days (2,000 Baht or 62.5 USD per hour)	Questionnaire survey
- Netting around the pond	- Total price of the net tight to the ground around the pond is about 4,000 Baht or 125 USD per pond 1 rai (0.16 ha)	Questionnaire survey
- Early harvesting	- If harvesting is done too earlier to avoid flooding, approximately 40% from the benefit (damage avoided) when shrimp attain the market size will be received	In-depth interview during questionnaire survey
- Shift calendar and stop culturing the shrimp	- If shrimp farmer choose change calendar or stop rearing during flooding period (September-October), 100% loss of income when shrimp attain the market size is the consequence for particular crop	In-depth interview during questionnaire survey
Costs for maintenance		
- Dike height increase	- Annual maintenance cost for increasing the height of dike is about 50% from the initial investment cost	In-depth interview during questionnaire survey
- Netting around the pond	- Netting around the shrimp pond is normally used only once to prevent the escape of shrimp.	Questionnaire survey

Once costs and benefits are identified, they would have to be converted into a monetary term either B/C ratio or net present value (NPV) by using the equation 8 and equation 9. B/C analysis was done by calculating the costs and benefits with a time horizon starts in 2014 (t = 0) until 2064 or for the next 50 years (t = 50). A broad range of discount rates has been used in the cost benefit analysis (CBA). This is a useful tool to make current costs and future benefits comparable. In this study, the discount rate of 2.7% was used as the low rate. This rate was prescribed by the Central Intelligent Agency in the CIA world factbook and conformed to the notes from Parry (2007). We also included an analysis using a discount rate of 4% as a relatively higher rate. In addition to taking the ratio of benefits to costs, the net present values showing the total discounted costs subtracted from total discounted benefits over the life-time of measures were also carried out. It is important to note that CBA was done under the assumption that all structural measures selected for CBA analysis could completely prevent the damage by floods. Moreover, external factors that could increase shrimp production costs were not included in the analysis of CBA. These include shrimp fry price and feed price, increasing excavator cost per hour, increase of net price and increase in labor costs.

Tests of robustness of results were deem necessary and were performed using sensitivity analysis on uncertain variables. Even though the assessment assumes that all shrimp farms in the flood risk map will receive and act upon advisories by taking structural control measures to protect their farms from flooding. In reality, there always be a chance of some small portion of shrimp farmers will not receive any advisories or simply decide to ignore them, have no adequate financial means, or will not be able to take actions due to other reasons. There is also a chance that structural flood control measures may be ineffective due to damages or failure of the system. The sensitivity analysis is; therefore, required for each of the uncertain variables and is used in the assessment. Once all costs and benefits associated with each flood risk protection measure have been identified, the option which yields the greatest net benefit can be identified.

3.7 Policy implication under climate change scenario

Since the change in the variables within the model can be the result of changing the likelihood of vulnerability level. The changes can be result of the different adaptation applied to the model of flood risk or from the changes to vulnerability indicator particularly cumulated rainfall. Therefore, interactions among indicators related to adaptation can be simulated to reduce future vulnerability in the study area. To draw out as huge figure impacted the whole areas of shrimp farms that are likely to be inundated by floods, policy implications based on the results of vulnerable map, risk map and adaptation practices was examined.

In this section, public participation meeting with community leaders was used to exchange the opinions and lead the suggestions from community leaders who were also shrimp farmers and flood victims in order to formulate adaptive strategies and requirements. Besides, preference adaptive strategies and barriers obtained from the public have been reviewed together with expert from Department of Fisheries.

However, not only the case study but also shrimp farms in other provinces of Thailand was taken into account to draw the policy implication. The general approach for the current synthesis is to highlight the results available in literature on impacts, adaptation and vulnerability of shrimp farming areas in Thailand to flood, and present these results in summary form. In order to achieve the objective of the study, general methodologies are listed below:

1) Collecting existing literature of flood impacts issues on shrimp farming in Thailand, available both nationally and internationally;

2) Digging into existing literature to find out and collate key findings therein by taking into consideration of methodological rigour that had been applied to reach a conclusion of the dissertation;

3) Assessing the potential adaptive measures for different shrimp farming systems and areas;

4) Developing and prioritizing better management practices to prevent the damage by floods

5) Briefly highlighting on the ground adaptation practices as reported in literature; and highlighting gross limitations of the synthesis study.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Establishing vulnerability indicators

Within the vulnerability assessment literature, indicators are measurable values for assessing the level of vulnerability. The use of vulnerability indicators representing the level was used for assessment process. The key element of indicators makes the level of vulnerability more tangible. However, the selection of the indicators that are relevant to the area of the study is essential to make the vulnerability assessment more realizable.

As vulnerability indicators as issues that enable to assess the community vulnerability level. A change in the value of indicator will certainly change the level of vulnerability. This interaction between the vulnerability indicator and change of level of vulnerability will be primary concern within my vulnerability modeling. However, a complete set of indicators could not be applied in the same period of time as only some vulnerability indicators are reflect a comprehensive approach to representing shrimp farmers perspectives. In addition, a complete list of indicator without selection the most relevant indicators cannot be included in the model due to computational challenges. Therefore, a process of vulnerability modeling is required to identify the indicators which are most relevant to the case study and represent key issues across the shrimp farmer in the study area. Therefore, identifying vulnerability indicators was begun with a comprehensive list of potential vulnerability indicators suggested by relevant literature. In this study, list of vulnerability indicators that is available in the website of Unesco-IHE Institute for Water Education (http://unesco-ihe-fvi.org/) was used as mainly source for identification of the relevant indicators. The list of indicators is then finalized by testing its relevant to the study area through preliminary questionnaire survey. The preliminary questionnaire survey conducted on November 2012 was used to answer for both purposes: to test the effectiveness of the set of questions in the questionnaire and to identify relevant vulnerability indicator based on four components whether social, economic, environment and physical. The survey was conducted mostly at Bang Khla district where was most devastated by floods every times of flood occurrence. Twelve victim shrimp farmers in which some of them are also community leader were interviewed to seek their perspectives on the vulnerability indicators.

A tallying approach for counting the total number of agreed respondents for each indicator was done during the preliminary site survey. In the case of convergence if the number of respondents who agree is greater than disagree for ratio two/third, the indicator become final vulnerability indicators for the vulnerability assessment. Conversely, if the total number of respondents who agree is low, the selected vulnerability indicator raised for the convergence is still insufficient for approving the factor. This approach was applied only for certain indicator listed in the website of Unesco-IHE Institute for Water Education. Notes even though this technique could identify the vulnerability indicator effectively, some shrimp farmers could possibly have a misconception while conducting the tallying for each indicator due to insufficient knowledge.

Table 4.1 shows a comparison of the tallying results from the site survey on November 2012. These selected indicators were then used for the refining the questions in the questionnaires before conducing questionnaire survey in the first quarter of the 2013. The selection also indicates selected and eliminated vulnerability indicators based on the list of vulnerability indicators given by Unesco-IHE Institute for Water Education. Moreover, two vulnerability indicators were suggested by respondents to be included for the vulnerability assessment. Obviously that the shrimp farms located in Bang Nam Prio district will be affected from the floodway policy. Another fact caused the devastation flood and observed from the site survey is the runoff from nearby province especially from Nadee and Pachantakham districts, Prachinburi province. These two evidences were taken into account as one of the vulnerability indicators for further assessment.

Table 4.1 A comparison between number of respondents who agree from the tallying process for convergence and results of the selection as vulnerability indicators for the assessment.

Flood vulnerability	Overall indicators								
	Relationship between component and factors								
	Exposure			Susceptibility			Resilience		
		Number of respondent who agree	Approval as one of vulnerability indicator (yes/no)		Number of respondent who agree	Approval as one of vulnerability indicator (yes/no)		Number of respondent who agree	Approval as one of vulnerability indicator (yes/no)
Social Component	Population density	9	Yes	Past experience	11	Yes	Warning system	10	Yes
	Population in flood area	10	Yes	Education (literacy rate)	10	Yes	Evacuation routes	2	No
	Closeness to inundation area	5	No	Preparedness/Awareness	12	Yes	Institutional capacity	4	No
	Population close to coastal	4	No	Child Mortality	0	No	Emergency service	9	Yes
	Population under poverty	8	Yes	Communication penetration rate	11	Yes	Shelter	3	No
	% of urbanized area	8	Yes	Population with access to sanitation	4	No			
	Rural population	4	No	Rural population who access to WS	5	No			
	Cadastre survey	4	No	Quality of water supply	2	No			
	Cultural heritage	1	No	Quality of energy supply	3	No			
	% of disable	1	No	Population growth	4	No			
				Human health	4	No			
				Human development index	4	No			
				Urban planning	10	Yes			
Economic component	Land use	12	Yes	Unemployment	9	Yes	Investment in c. measure	11	Yes
	Proximity to river	8	Yes	Income	12	Yes	Infrastructure management	0	No
	Closeness to inudation area	5	No	Inequality	2	No	Dams & storage capacity	3	No
	% of urbanized area	8	Yes	Yearly volume	2	No	Flood insurance	8	Yes
	Cadastre survey	4	No	Life expectancy index	8	Yes	Economic recovery	3	No
				Urban growth	2	No	Past experience	11	Yes
				Child mortality	0	No	Dikes/levees	12	Yes
				Regional GDP/capita	2	No			
				Urban planning	10	Yes			
Environmental component	Ground WL	3	No	Natural reservations	8	Yes	Recovery time to floods	12	Yes
	Land use	12	Yes	Years of sustaining health life	2	No	Environmental concern	3	No
	Over used area	3	No	Quality of infrastructure	3	No			
	Degrated area	2	No	Human health	4	No			
	Unpopulated land area	2	No	Urban growth	2	No			
	Types of vegetation	8	Yes	Child Mortality	0	No			
	% of urbanized area	8	Yes	Rainfall	12	Yes			
	Forest change rate	8	Yes	Evaporation	2	No			
Physical component	Topography (slope)	12	Yes	Building codes	2	No	Dam & storage cpacity		
	Heavy rainfall	12	Yes	Frequency of occurance	12	Yes	Roads		
	Flood duration	12	Yes				Dikes/Levees		
	Return period	10	Yes						
	Proximity to river	8	Yes						
	Soil Moisture	9	Yes						
	Evaporation rate	2	No						
	River discharge	8	Yes						
	Flow velocity	5	No						
	Storm surge	0	No						
	Rainfall	12	Yes						
	Flood water depth	5	No						
	Sedimentation load	2	No						
	Yearly volume	5	No						

As shown in Table 4.1, twelve respondents assessed 74 vulnerability indicators. Only 33 from total indicators were agreed by respondents. Some of indicators could incorporate into one indicator. For instance, rainfall and heavy rainfall could incorporate to rainfall indicator. Moreover, the combination of land use, type of vegetation and percentage of urbanized area can be found from the land use map provided by Department of Land Development. Meanwhile, drainage density was produced using GIS under the combination between proximity to river and river discharge to evaluate the ability of the area to drain volume of flooded water.

Based on the process above, there were totally 26 vulnerability indicators for my case study as set out in Table 4.2. There were six indicators related to physical component to be assessed for physical vulnerability. Meanwhile, the rest of indicators were used to assess for social vulnerability. In addition, past flood experience and return period were excluded from the vulnerability assessment. Conversely, these indicators were used as one of the element for flood risk modeling instead.

When considering each vulnerability indicator which was derived from literature and stakeholder's opinions; however, more work to gain the sufficient information for establishing vulnerability assessment is essential. Based on the list of indicators shown in Table 4.2, I applied two methods for collection of the relevant information of each indicator. Firstly, the secondary data was collected using literature review. Most of secondary data was used for physical vulnerability assessment. Secondly, primary data which is related to socio-economic condition of shrimp farmers in the study area as shown in Appendix B was collected using questionnaire survey and in-depth interview with the victim. This information was used for social vulnerability assessment.

Table 4.2 Final vulnerability indicators for the case study.

Factor of vulnerability	Type of Component	Indicators
Exposure	Social component	Shrimp farmer population density (Pd)
		% of small shrimp farmer (SM)
		Population under poverty (Pp)
		Forest change rate (FCR)
	Physical	Rainfall (Rf)
		Slope (Sl)
		Drainage density (Dd)
		Soil texture (Lt)
		Land use (Lu)
		Size of basin (Sb)
		Designated floodway from government (DFF)
		Runoff from nearby province (RF)

Susceptibility	Social component	Past experience (PE)
		Education (Ed)
		Preparedness/awareness (A/P)
		Communication penetration rate (CPR)
	Economic	Debt to income (DI)
		Wealth (saving status) (SS)
		Unemployment (UM)
		Life expectation for shrimp farming (LEI)
	Environmental	Natural reservation (NR)
	Physical	Frequency of occurrence (FO)
Resilience	Social component	Warning system (WS)
		Emergency service (ES)
	Economic	Recovery time to floods (RIF)
		Flood insurance (FI)

It is important to note that physical vulnerability assessment was assessed through the definition of sets of indicators based on previous literature and on the available data for the study site. For instance, literature on the flood vulnerability assessment in neighboring countries (Adiat, 2012; Yahaya, 2010; Lawal, 2012; Yalcin, 2004) were used to make a set of indicators related to physical vulnerability assessment. Even though some physical indicators suggested by Unesco-IHE Institute for Water Education especially river discharge and temperature were not used for assessing physical vulnerability due to unavailability of the data, other physical indicators especially size of basin and drainage density were recommended by literature and expert. These indicators are normally used to assess flood vulnerability in other areas even though they are not listed in the website of Unesco-IHE Insitute for Water Education.

4.2 Current vulnerability scenario

The assessment of the flood vulnerability of shrimp farms in Chachoengsao Province comprises two components adopted from the Adaptation Policy Framework by Downing (2012) : (1) assessing the current vulnerability of shrimp farms to flood occurrence by using typical hydrological, physical and environmental components as the primary data and (2) assessing the social vulnerability of shrimp farmers who were victim from the last several floods events. Geo-environmental characteristics have been applied to assess the flood-vulnerable areas in the first component of the current vulnerability assessment. The second component involves incorporating a site survey and interviews with the shrimp farmers who have been affected by severe floods to identify their socio-economic conditions for further assessment of adaptive capacity. Although the results of each aspect were interpreted separately in this study, the associations between the two aspects were considered in the conclusion.

4.2.1 Physical vulnerability

A multicriteria evaluation is a fundamental step for rational decision making, and GIS is commonly used for flood risk analysis. Based on the study of other relevant basin sites, vulnerability assessments typically focus on physical vulnerability. Physical characteristic changes (especially land cover change) usually result in a decrease in the potential infiltration and an increase in the runoff rate (Mustafa, 2005; Bojie, 2013). To generate a flood map and examine the vulnerability, this research used a cumulative rainfall threshold for flooding. The assessment of the flood-vulnerable areas of shrimp farms involved the following steps:

4.2.1.1 Identifying a vulnerability indicator

The available data on the flood vulnerability index (FVI) and the results of similar studies (Balica, 2012; Agbola et al., 2012; Marchi et al., 2010; Borga et al., 2011; Kia et al., 2012) were used to identify vulnerability indicators of flood occurrence. List of vulnerability indicators suggested by Unesco-IHE Institute for Water Education was brought to guide which indicator related to physical should be adopted for further assessment. The vulnerability indicators in this study relate only to exposure, i.e., rainfall, slope, drainage density, soil texture, land use, and basin size, according to the geo-environmental characteristics of the study area. At this stage of the study, two components (sensitivity and adaptation capacity) were not incorporated into the vulnerability assessment; these components were studied and reported in the next section. The effects of the exposure indices on flood occurrence were defined as follows:

i. Rainfall (Rf) represents the volume of water available for infiltration and runoff (Adiat, 2012). Extremely heavy rainfall events are often associated with flash floods. The daily rainfall records for Chachoengsao Province were provided by the Meteorological Department of Thailand and were used to produce a rainfall map for the study area.

ii. Slope (Sl) is a factor that controls the rate of infiltration (Prasad et al. 2008). The surface runoff is low when the slope of an area is rather flat because low-angle slopes allow rainwater to percolate. Consequently, flat areas are highly susceptible to flooding. In contrast, steep slopes facilitate high runoff, allowing less time for rainwater to percolate. Hence, steep areas are less vulnerable to flooding. To generate the slope map of the study area, a digital elevation model (DEM) with a **30**-meter spatial resolution was obtained from the Royal Thai Survey Department. The slope (percentage) was classified in accordance with Adiat (2012) using ArcGIS® software version 10 by ESRI.

iii. Drainage density (Dd) is calculated as the total length of all of the streams and rivers in a basin divided by the total area of the basin. The spatial analysis tool of ArcGIS® software version 10 by ESRI was used to generate and classify a gridded drainage density map. The drainage density indicates the spacing of channels (Prasad et al., 2008). When the drainage density is high, the soil is largely impermeable, leading to a low infiltration rate and high flood vulnerability.

iv. Soil texture or lithology (Lt) is an important factor in determining the infiltration rate. The soil type or texture greatly influences the rate of infiltration in soil and in the drainage development. When a low infiltration rate or high degree of runoff is observed, the flood susceptibility is high (Eze, 2011; Chandra, 2012). A 2009 soil map showing 39 soil series in the province was obtained from the Department of Land

Development of Thailand. The infiltration rates estimated by the Department of Land Development were used to classify the soil series into four categories in ArcGIS® software version 10 by ESRI: poor, moderate, good and very good infiltration rates.

v. Land use (Lu) is associated with the intensity of runoff and flood frequency. A 2010 land use map provided by the Department of Land Development of Thailand was used for this research. A total of 14 land use types were grouped into five classes, as suggested by Chawala (2008) and Rosca (2012), in ArcGIS® software version 10 by ESRI.

vi. Size of basin (Sb) is the area that accumulates rainfall in a basin. The basin size directly influences the total volume of runoff. A small basin or catchment, i.e., less than 1,000 km^2, can be commonly affected by flash floods as a result of intense rainfall, and response times are on the order of a few hours or less (Marchi et al., 2010). To determine the basin size, the spatial analysis tool in ArcGIS was used.

4.2.1.2 Assessment of areas currently vulnerable to floods

1) Pairwise comparison method

The pairwise comparison method is a powerful tool used to establish the relative order between different concepts in situations in which explicit weighting and rating are difficult and to support the decision-making process in the form of a reciprocal decision matrix (Deng, 1999). In this study, a pairwise comparison matrix was used to determine weights of flood plain characteristics based on the findings of several studies that conducted similar flood assessments (Lawal, 2012; Musungu, 2012). Then, the weights assigned by these results were applied to rank the factors from 1 to 9 according to the fundamental scales of the analytic hierarchy process (AHP) (Saaty, 1980), as shown in Table 4.3. Based on the results of Agbola et al. (2012), Borga et al. (2011), Kia et al. (2012) and Marchi et al. (2010), the major factors that cause flooding in the watershed include annual rainfall, watershed/basin size, slope, gradient of the main drainage channel, distance from main river, drainage density, land use and soil texture. In this study, 6 factors were selected: drainage density or capacity of existing drainage, rainfall, soil texture (lithology), slope, basin size, and land use/land cover.

With guidance from an expert from the Department of Fisheries, Thailand, and the relevant literature (Adiat et al., 2012; Yahaya et al., 2010; Lawal et at., 2012; Yalcin and Akyurek, 2004), we determined the weight of each indicator shown in Table 4.4 for the decision-making process of AHP (Saaty, 2008). To determine the weights of each factor, a pairwise comparison matrix between two factors (row and column) was constructed. For instance, if the factor in the row has more importance than the factor in the column, then the magnitude of the importance (i.e., 1, 3, 5, 7 or 9) is indicated. If the factor in the row has a lower importance than the factor in the column, then the value of the weight is equal to 1 divided by the magnitude of the importance. Based on the result shown in Table 4.4, giving weight between cumulative rainfall and land cover/use was particularly determined by expert's judgment based on relevant literature. Land use is much lower important than the cumulative rainfall. The reason is because we concluded that indicators except land use are dominating river and/or runoff flow at landscape scale. As the pairwise comparison was conducted at the present time, effect of land use influenced on flood occurrence will become the most important if there is change on land use. In particular, the changes in land use associated with urban development affect flooding in several ways e.g. increase flood hazard and effect on flood flows. Therefore, the effect of land use is likely to become less important with increasing scale of consideration at the present time, in particularly, when comparing to cumulative rainfall. The results of the nth roots, which were summed over the first row, were used to normalize the eigenvector elements. Then, the first element in the eigenvector was derived from the sum of the first row divided by the summed nth roots product value (Table 4.5). To ensure consistency in the determined weights from the pairwise comparison, the consistency ratio (CR) was analyzed using equation (1). To be consistent, the CR value must be less than 0.1 (Saaty, 1980; Vahidnia, 2008).

$$CR = \lambda_{\max} - n/(n-1)/RI \qquad (1)$$

where λ is the maximum eigenvalue of the matrix, n is the number of elements in the matrix, and the RI (random index) values were adopted from Saaty (1980), as shown in the table below. The table shows the average consistency index, which was randomly generated (i.e., inconsistent) using the pairwise comparison matrices.

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

By adopting the steps described by Saaty (1980), the consistency ratio was 0.073 divided by 1.24 (0.06). Because this value is less than 0.1, the estimated weights shown in Table 4.5 can be reasonably adopted.

It is important to note that the result of vulnerability assessment depends on the expert's opinion. Number of expert in wide-ranging expertise is useful for further assessment, but the method for capturing experts' opinions using the pairwise comparison method and the method for aggregating individual expert ratings (in cases where consensus ratings are not used) as well as the method for standardizing the criteria or factors involved in the analysis need to be taken into account (Ouma, 2014).

Table 4.3 Scale for pairwise comparison (Saaty, 1980; Saaty, 1991).

Magnitude of importance	Description
1	Equal importance
3	Moderate importance
5	Strong importance or essential
7	Very strong or demonstrated importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between adjacent scale values

Table 4.4 Square pairwise comparison matrix for the selected flooding vulnerability indicators.

	Drainage density	**Size of basin**	**Cumulative rainfall (10 days)**	**Soil texture**	**Slope**	**Land cover/use**
Drainage density	1	1	0.33 (1/3)	3	3	5
Size of basin	1	1	0.33 (1/3)	3	5	5
Cumulative rainfall (10 days)	3	3	1	5	5	9
Soil texture	0.33 (1/3)	0.33 (1/3)	0.20 (1/5)	1	3	3
Slope	0.33 (1/3)	0.33 (1/3)	0.20 (1/5)	0.33 (1/3)	1	3
Land cover/use	0.20 (1/5)	0.20 (1/5)	0.11 (1/9)	0.33 (1/3)	0.33 (1/3)	1
Column total	5.87	5.87	2.18	12.67	17.33	26.00

Table 4.5 Determination of the relative criterion weights.

	Drainage density	Size of basin	Cumulative rainfall (10 days)	Soil texture	Slope	Land cover/use	n^{th} root of products of value	Eigenvector
Drainage density	0.17	0.17	0.15	0.24	0.17	0.19	1.10	0.1827
Size of basin	0.17	0.17	0.15	0.24	0.29	0.19	1.21	0.20193
Annual rainfall	0.51	0.51	0.46	0.39	0.29	0.35	2.51	0.418544
Soil type	0.06	0.06	0.09	0.08	0.17	0.12	0.57	0.09548
Slope	0.06	0.06	0.09	0.03	0.06	0.12	0.40	0.067478
Land cover/use	0.03	0.03	0.05	0.03	0.02	0.04	0.20	0.033868
Column total	1.00	1.00	1.00	1.00	1.00	1.00	6	1.00

2) Assigning vulnerability rating to the indices

The index ranges of flood vulnerability are based on the exposure vulnerability factor. The classes of thematic layers for all indices and their corresponding ratings are shown in Table 4.6. The flood vulnerability rates were assigned to each class according to the magnitude of influence of the class on flood occurrence. The ratings range from 1 to 5: (1) very low, (2) low, (3) moderate, (4) high, and (5) very high flood potential. To classify the influence of each index on flood occurrence, the results from relevant studies and similar research papers for flood vulnerability assessment (Adiat et. al., 2012; Chawala 2008; Rakwatin et al., 2013; Rosca and Iacob 2012) (Table 4.6) were reviewed and used as a reference, with the exception of cumulative rainfall, which relied on actual statistics. The cumulative rainfall from day 3-10 in September and the beginning of October in 2005, 2006, 2008, 2011 and 2012, when flash floods occurred in the study area, were used to assign the classes. The worst flood in Chachoengsao Province occurred in 2011, when flood water from upstream of the basin flowed into the study area at the same time heavy rainfall caused a flash flood. The cumulative rainfall levels in Chachoengsao in September of 2005, 2006, 2008 and 2011 from Thai Meteorological Department rain gauge stations were 350.5, 404, 381.5 and 362.8 mm, respectively. These rainfall amounts were 26.3%, 45.5%, 37.5% and 30.7% higher, respectively, than the normal monthly rainfall quantity based on the 30-year September average (277.5 mm for 17 rainy days). To determine level of susceptibility of cumulate rainfall, we assumed that the rain is falling over the entire area of Chachoengsao province because only rainfall data collected by only Chachoengsao weather station and rain gauge were used to project the map for physical vulnerability. Furthermore, the 300 mm of cumulative rainfall that fell during Tropical Storm Gaeme during September 16-25, 2012, as reported by the Chachoengsao Provincial Office of Disaster Prevention and Mitigation, was the threshold for flash floods in 2012. Therefore, this situation, i.e., 300 mm of cumulative rainfall over 10 days leading to flooding in September 2012, was used to classify the areas that are highly susceptible to floods. The current rainfall threshold for triggering floods in the study area does not differ significantly from the Extreme Rainfall Alert (ERA) service launched by the Environmental Agency and the Methodological Office for England and Wales: The rainfall thresholds are set to 30 mm in one hour, 40 mm in three hours, and 50 mm in six hours (Hurford et al., 2012). The average intensity of storms that leads to flooding in Greece is 4.5 mm/hr; this threshold was also taken into account (Diakakis, 2012) to guide the rainfall index classification, i.e., high, moderate, low and very low flood susceptibility.

Table 4.6 Rating for classes of factors.

Influential indices	**Category (classes)**	**Susceptibility to flooding**	**Rating (R)**	**Normalized weight (W)**
Drainage density (Dd) (km/sq.km)	0 – 0.019[a]	Very low	1	0.1827
	0.019 – 0.06[a]	Low	2	
	0.06 – 0.13[a]	Moderate	3	
	0.13 – 0.28[a]	High	4	
	> 0.28[a]	Very high	5	
Size of basin (Sb) (sq. km)	<1,000[b]	Very high	5	0.20193
	1,001 – 1,800[b]	High	4	
	1,801 – 2,600[b]	Moderate	3	
	>2,601[b]	Low	2	
Cumulative rainfall (Rf) (mm within 10 days)	<150	Very low	1	0.418544
	150 – 200	Low	2	
	200 – 250	Moderate	3	
	250 – 300	High	4	
	>300[c]	Very high	5	
Soil texture (Lt)	Very good infiltration rate[b]	Low	2	0.09548
	Good infiltration rate[b]	Moderate	3	
	Moderate infiltration rate[b]	High	4	
	Poor infiltration rate[b]	Very high	5	
Slope (Sl)	0 – 2% (flat)[a]	Very high	5	0.067478
	2 – 8.47% (undulating)[a]	High	4	
	8.47 – 15.88% (rolling)[a]	Moderate	3	
	>15%[b] (steep)	Low	2	
Land cover/use (Lu)	Paddy field and	Very high	5	0.033868
	moorland[b,d]	High	4	
	Area with complex crops[b,d]	Moderate	3	
		Low	2	

	Pastures urban and rural space ^{b,d}	Very low	1
	Perennial and horticulture area^{b,d}		
	Forest area^{b,d}		

Sources: ^{a} Adiat et. al. (2012)

^{b} Chawala (2008)

^{c} Rakwatin et al. (2013)

^{d} Rosca and Iacob (2012)

3) Conversion of thematic layer to point layers for the flood vulnerability index (FVI)

The proposed general FVI in Equation (2) links the values of all indicators to flood vulnerability components and factors (Balica, 2012; Balica et al., 2013), where E, S and R represent exposure vulnerability, sensitivity vulnerability and resilience or adaptation vulnerability, respectively.

$$FVI = E * S / R \qquad (2)$$

At this stage, the research primarily aims to map the flood-vulnerable area of shrimp farms based on geographical and hydrological characteristics. The resilience and sensitivity factors were omitted from the FVI assessment (Equation 2); these factors will be further assessed in the next section to identify the adaptation capacity to reduce the flood vulnerability. Therefore, only 6 factors from the vulnerability indicators were used to generate the raster map and to analyze the flood vulnerability with the assigned weight (W) and rating (R). The flood vulnerability index (FVI), which is the summation of the products of the normalized weight and the rating for all the factors, was calculated as follows.

$$FVI = Rf_W Rf_R + Dd_W Dd_R + Sb_W Sb_R + Lt_W Lt_R + Sl_W Sl_R + Lu_W Lu_R$$

4) Assessment of the flood-vulnerable area

Each vulnerability indicator was produced as raster layer in ArcGIS spatial analysis before aggregation to produce the current vulnerability map in term of physical vulnerability assessment. Figure 4.1 and 4.5 show the raster layer of vulnerability indicator starting from drainage density, basin size, soil texture, slope and land use, respectively. Overlaid raster layers consisting of a gridded array of cells in ESRI ArcGIS and a multicriteria evaluation using the FVI equation were used to determine the area vulnerable to flooding. The factors were weighted and rated according to their relative importance using the spatial analysis tool in ArcGIS. Then, the flood-vulnerable area was identified. Flood vulnerability was divided into 5 categories based on the vulnerability potential in the event of flooding (Table 3.5 of Chapter 3) according to percentile thresholds (i.e., 0-20%, 20-40%, 40-60%, 60-80% and 80-100%). The locations of shrimp farms in Chachoengsao Province were overlaid with the flood-vulnerable area to identify areas where shrimp farms are susceptible to flooding and where adaptation practices should be prepared in advance. Shrimp farms that are located in the flood-vulnerable areas are likely to be severely damaged. According to the study by Muralidhar (2010), the flooding of shrimp ponds causes total damage to cultured shrimp.

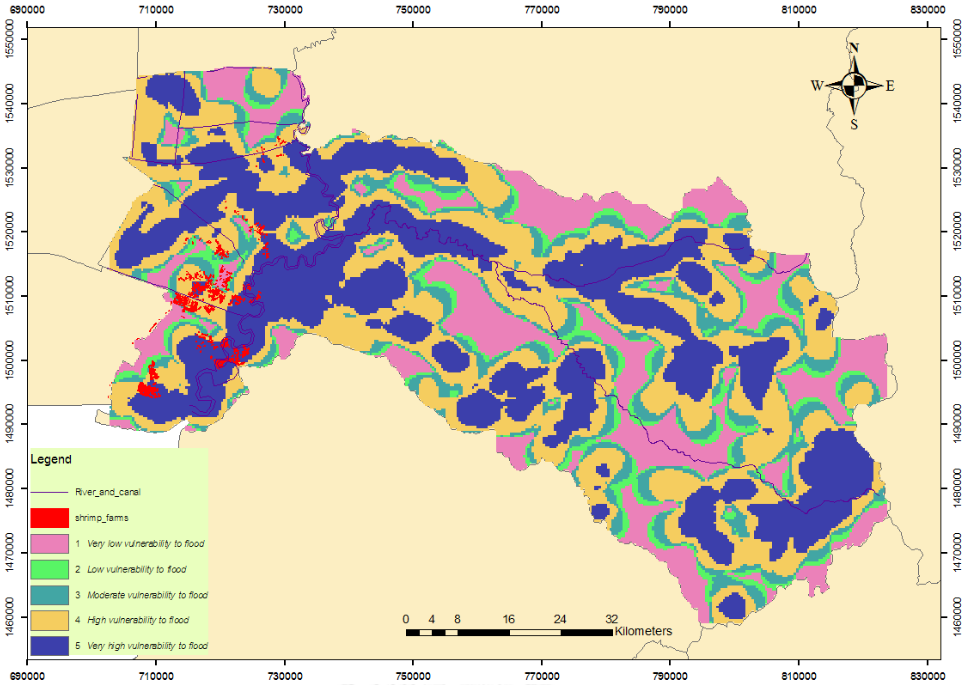

Figure 4.1 Raster layer of the drainage density.

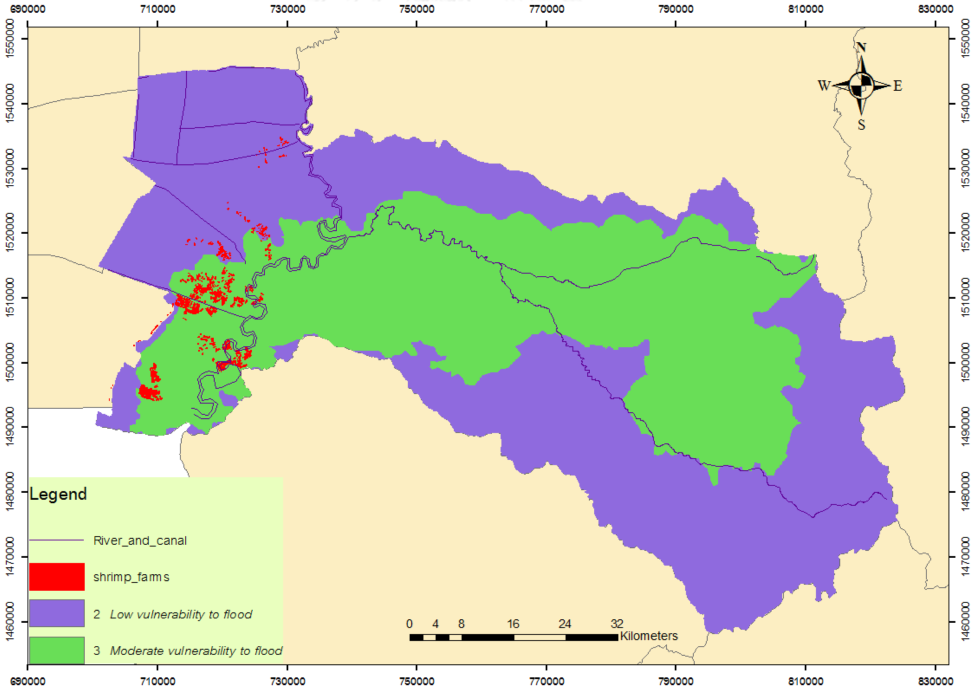

Figure 4.2 Raster layer of the basin size.

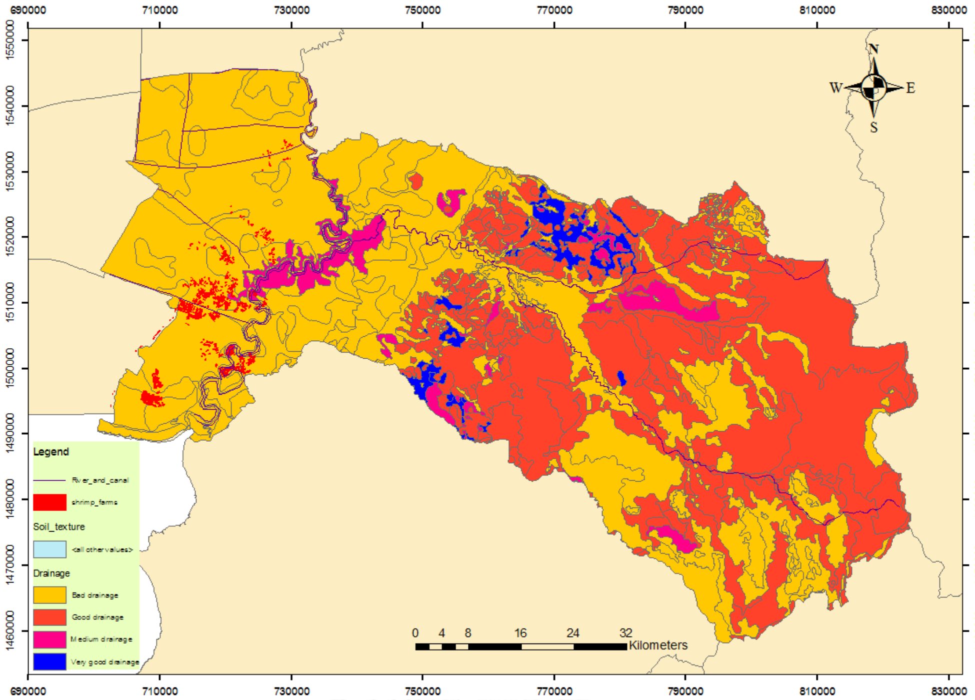

Figure 4.3 Raster layer of the soil texture.

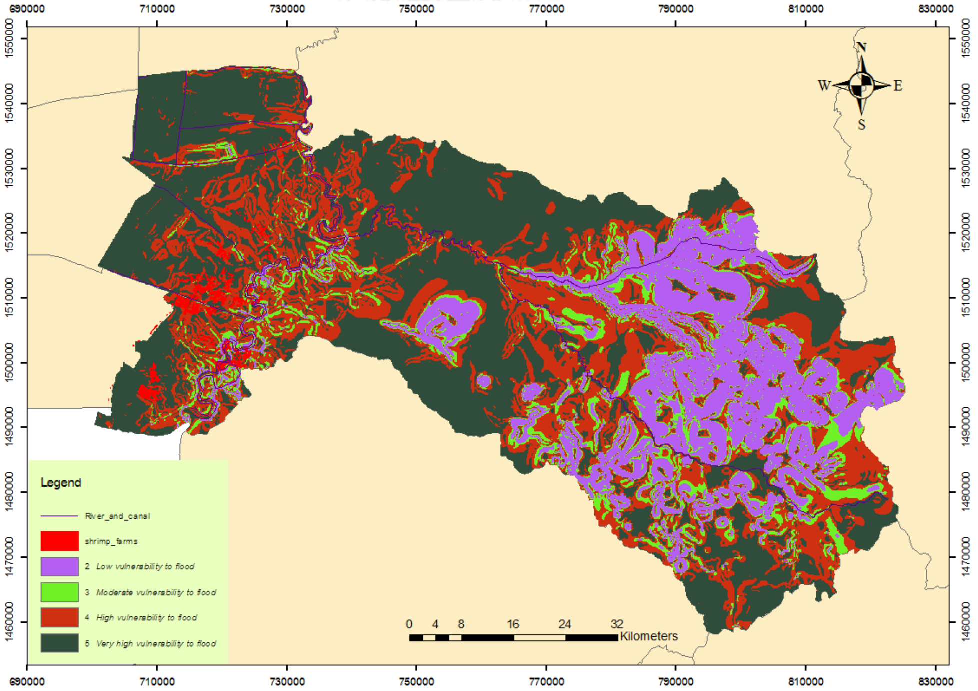

Figure 4.4 Raster layer of the slope.

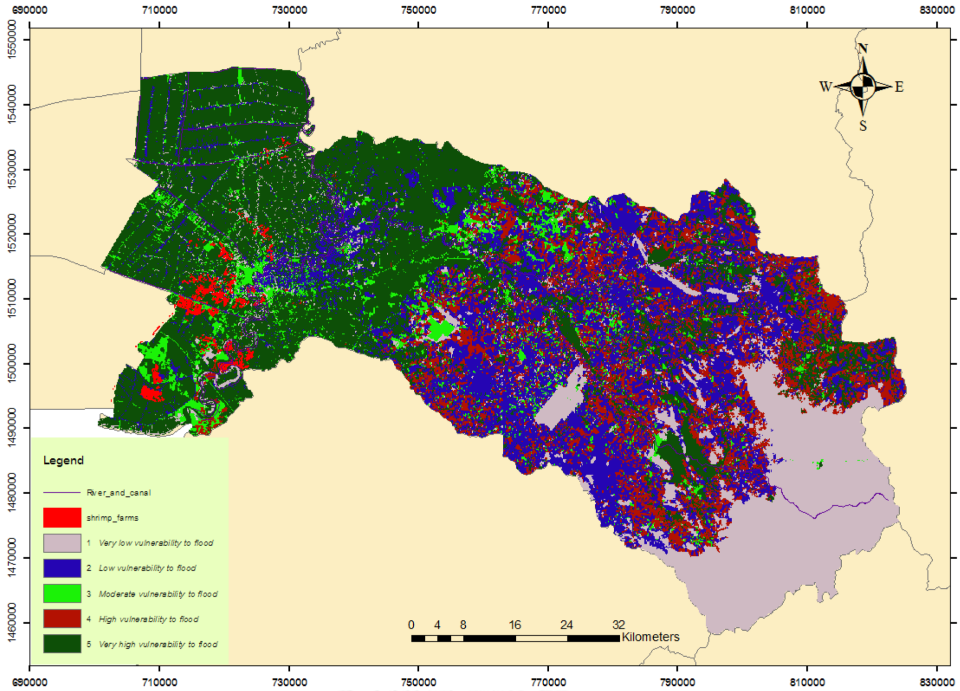

Figure 4.5 Raster layer of the land use.

4.2.1.3 Current area of flood-vulnerable shrimp farms based on physical vulnerability

For our assessment of flood occurrence, the precipitation data were combined with the vulnerability indictors of the existing raster map to generate the flood vulnerability map shown in Figure 4.6. According to the Thai Meteorological Department, the average cumulative rainfall for Chachoengsao Province in September, when the maximum annual rainfall occurs based on the 30-year average, was 277.5 mm. This value which is threshold for triggering flood in study area was used as a key indicator to project the current flood-vulnerable area. The rainfall indicator was converted into raster data or grid file. The vulnerable area was classified into areas of moderate (3), high (4) and very high (5) susceptibility to flooding. Approximately 85.3% of the area was classified as a highly vulnerable zone, 8% was classified as a very highly vulnerable zone and 6.5% was classified as a moderately vulnerable zone. The majority of the study area is highly vulnerable to flooding; thus, nearly the entire study area is susceptible to inundation when the cumulative 10-day rainfall is 250-300 mm.

More than 8,000 shrimp farms and more than 29,157 shrimp ponds are located in Chachoengsao Province. These data were overlaid with the current vulnerable area to identify where shrimp farms are vulnerable to floods. The results revealed that almost all shrimp farms in Chachoengsao Province have high or very high vulnerability to flooding, as shown in Figure 4.6. Flooding can cause the complete shut-down of shrimp farms because massive numbers of shrimp escape during flood events.

From July 2011 to January 2012, Thailand experienced severe flooding due to heavy rainfall from five intense tropical storms. The cumulative rainfall during January-October 2011 was 1,647 mm, which is 42% higher than the 30-year average (Rakwatin, 2013). The cumulative rainfall from the 2011 flood event was used to model the worst-case flash flood that is likely to occur in the study area. The highest 10-day cumulative rainfall in September 2011, calculated from the daily rainfall data obtained from the Thai Meteorological Department, was approximately 325.9 mm, which was higher than the rainfall volume that initiated the flood risk in the assessment. Additionally, the maximum 10-day cumulative rainfall quantity that caused flooding in 2012, 300 mm, was also taken into account. The cumulative rainfall quantity of 325.9 mm was used to model the worst-case scenario when the cumulative rainfall quantities deviate from the average. Other selected vulnerability indicators, e.g., slope, drainage density, and basin size, were assumed to remain the same.

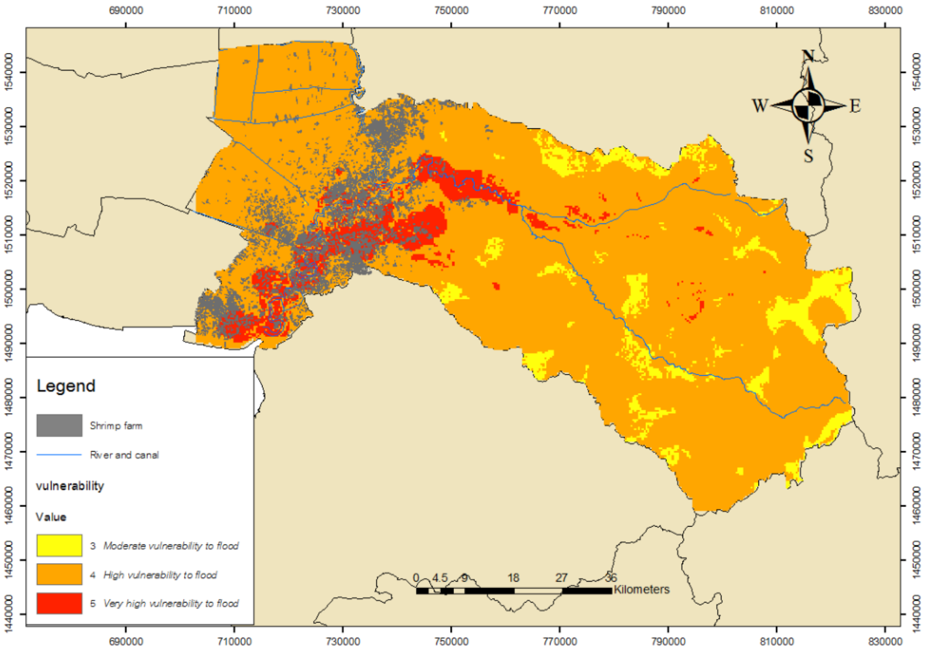

Figure 4.6 Current flood-vulnerable shrimp farm areas.

Figure 4.7 shows the result when heavy rainfall greater than the 30-year average occurs in the study area. The vulnerability area was classified as either highly or very highly vulnerable to flooding. Approximately 43.4% of the area was classified as highly vulnerable to flooding, and approximately 56.6% was classified as very highly vulnerable to flooding. Overlaying the shrimp farm map of Chachoengsao with the vulnerability map computed by the anomalous cumulative rainfall yielded significantly higher numbers of inundated shrimp farms and a large increase in the area very highly vulnerable to flooding.

The delineated flood-extent areas on October 30, 2011, based on GISTDA data, were overlaid with the results of the vulnerability map generated by the cumulative rainfall of 325.9 mm in September 2011 to validate the vulnerability map with the actual flooding events in 2011. According to Figure 4.8, nearly all of the shrimp farms in the study area were flooded in 2011. These results are consistent with the vulnerability assessment, i.e., most shrimp farms in the study area will flood when the 10-day cumulative rainfall is greater than 300 mm. Note that the mountainous and steeply sloping areas are located on the right side of Figure 4.8. Therefore, these areas lack shrimp farms and are unaffected by floods.

The change in the rainfall pattern due to climate change in Bangladesh, for instance, was reviewed. Flood events increased by approximately 70% compared with the annual average of 20.5% associated with typical rainfall levels (Monirul Qader Mirza, 2002). Obviously, a major change in the rainfall amount, particularly from tropical storms, could severely damage the shrimp farming industry because of the industry's concentration in flood-prone areas. Because of uncertainties in climate change impacts, participatory approaches and the assessment of adaptation options within areas vulnerable to flooding require further study.

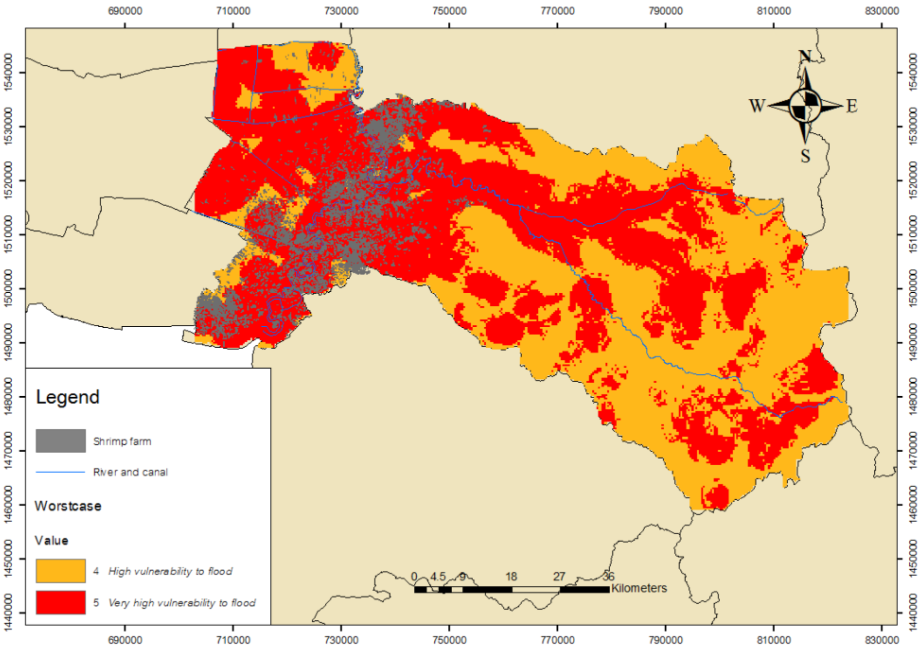

Figure 4.7 Degree of vulnerability of shrimp-farm areas when the 10-day cumulative rainfall is greater than 300 mm.

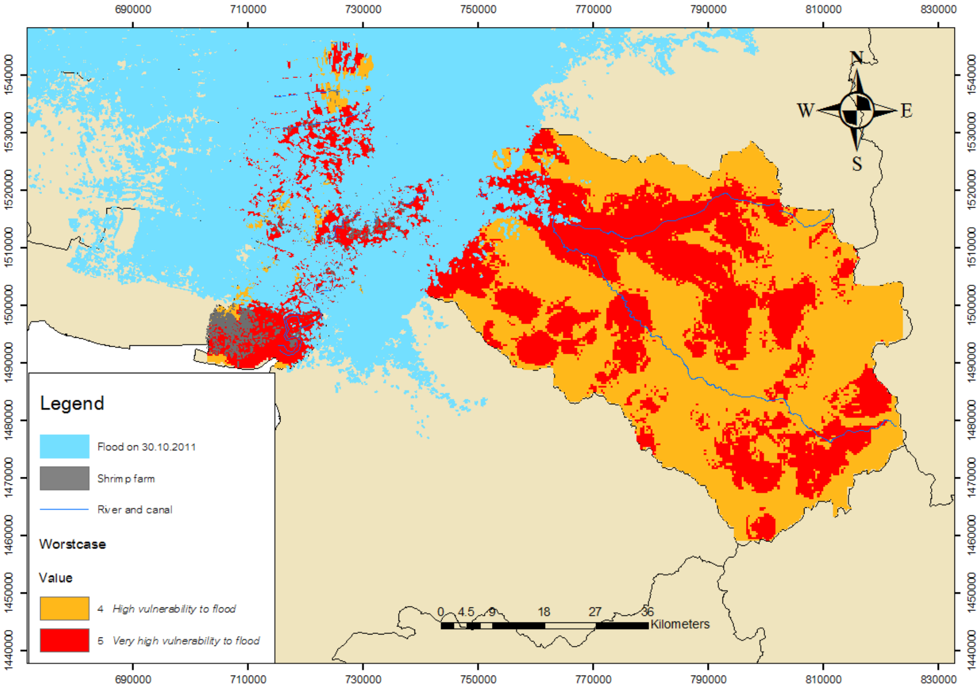

Figure 4.8 Flood extent on October 30, 2011, and flood-vulnerable areas according to the assessment.

Based on the result of physical vulnerability assessment, the combination of GIS and multicriteria evaluations has opened up new opportunities to overcome the challenges in assessing flood-vulnerable areas and implementing sustainable shrimp farming. GIS tools with a wide range of functions are now available for multiple purposes. In this study, flood vulnerability was assessed to identify the current flood-vulnerable shrimp farm areas in Chachoengsao Province, Thailand. Typical geo-environmental parameters were key components in the development of the vulnerability map of shrimp farms. The results revealed that shrimp farms in Chachoengsao are highly to very highly vulnerable to floods, although the assessment is only based on geographical data. Importantly, shrimp farms become more vulnerable to floods when the 10-day cumulative rainfall is greater than 300 mm.

4.2.2 Social vulnerability

Social vulnerability encompasses all of the factors determining the hazard due to flooding and its severity. A social vulnerability index score close to one (1) was assigned to those shrimp farms with high vulnerability. Districts where shrimp farms have experienced the impact from floods were examined to determine their social vulnerability. Six (6) out of a total of eleven (11) districts of Chachoengsao province are reported as vulnerable areas in this study. Table 4.7 shows the indices and ranks of social vulnerability in the six districts. The indices ranged from 0 – 0.957 for exposure, 0.430 – 0.848 for sensitivity, and 0.665 – 1 for adaptation (resilience). Once all of the components of social vulnerability were aggregated, the social vulnerability indices ranged from 0.477 – 0.845. Social vulnerability index analysis revealed that the levels of social vulnerability related to susceptibility and resilience among districts are not significantly different. In contrast, exposure, which is the main factor in vulnerability, was observed to differ significantly, especially in Bang Nam Priao, where exposure the score was equal to zero. This difference resulted from the poverty level, measured according to the income earned from shrimp farming. Shrimp farmers who live below the poverty threshold face a higher risk of flooding. The majority of shrimp farmers in Bang Nam Prio own large-scale shrimp farms, and their income from their shrimp farms is above the poverty line (above minimum wage). The primary determinants of financial stress do not pose a problem for shrimp farmers in the Bang Nam Prio district, even though some areas of Bang Nam Prio have been designated by the government as floodways. Thus, these indicators for shrimp farmers in this district cause the observed vulnerability to differ from that in other districts. Hence, these indicators became key factors for promoting the adaptive capacity.

A social vulnerability map was developed based on the social vulnerability index scores of each district as shown in Table 4.8. The map aids in determining the most and least vulnerable districts where shrimp farms are located. Moreover, it indicates potential hotspots of social vulnerability among shrimp farms in the area. Evidently, the most vulnerable districts are located adjacent to the Bangpakong River (Figure 4.9), stretching from the upper part to the lower part of the river. Districts with a social vulnerability index score greater than 0.6 and 0.8 are labeled as showing high and very high vulnerability, respectively. Five out of the six districts were classified in the high and very high social vulnerability categories. The Bang Khla and Ban Pho districts are considered to be the most socially vulnerable districts in Chachoengsao province. The fact that the greatest number of shrimp farming areas are located in these two districts (2,589 ha for Bang Khla and 2,166 ha for Ban Pho) is another reason to designate both districts as showing very high vulnerability.

It is important to note that even though social vulnerability index of Bangpakong district was lowest or less vulnerability, shrimp farms in Bangpakong district are still located in high and very high vulnerable area to flooding based on geo-physical characteristic of an area (Figure 4.6 and 4.7). As social vulnerability was assessed by interviewing with victims who have experienced previous flood; however, there was no evidence to show that shrimp farmers in Bangpakong district have also suffered certain damage. In particular, Chachoengsao Provincial Fisheries Office confirmed that no shrimp farmers in Bangpakong district were recorded as one of the 812 victims of the worse flood in 2011. Thus, particular concerns should be given to shrimp farms in Bangpakong district with adaptation options to reduce physical vulnerability even there is no data for Bangpakong district.

Table 4.7 Social vulnerability index and ranks by district in Chachoengsao province.

Vulnerability factor	**Indicator**	**Districts**[1/]					
		Ban Pho	**Bang Khla**	**Khlong Khuean**	**Muang**	**Ratchasan**	**Bang Nam Priao**
Exposure	Shrimp farmer population density (Pd)	3.67 (0.83)	4.38 (1.00)	3.90 (0.88)	0.35 (0.04)	0.29 (0.02)	0.18 (0.00)
	% of small shrimp farmers (SM)	100 (1.00)	100 (1.00)	87 (0.87)	100 (1.00)	100 (1.00)	0 (0.00)
	Population in poverty (Pp)	95 (0.95)	87 (0.87)	84 (0.84)	82 (0.82)	100 (1.00)	0 (0.00)
	Forest change rate (FCR)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
	Vulnerability index	**0.927**	**0.957**	**0.865**	**0.620**	**0.676**	**0.000**
Susceptibility	Government-designated floodway (DFF)	0 (0.00)	0 (0.00)	72.77 (0.72)	0 (0.00)	0 (0.00)	100 (1.00)
	Runoff from a nearby province (RF)	2 (1.00)	2 (1.00)	1 (0.00)	1 (0.00)	2 (1.00)	1 (0.00)

	Past experience (PE)	100 (0.00)	100 (0.00)	100 (0.00)	100 (0.00)	100 (0.00)	100 (0.00)
	Education (Ed)	2 (0.97)	0 (1.00)	0 (1.00)	0 (1.00)	0 (1.00)	66.66 (0.00)
	Preparedness/awareness (A/P)	66 (0.89)	53.84 (1.00)	81.81 (0.39)	60 (0.74)	100 (0.00)	100 (0.00)
	Communication penetration rate (CPR)	94 (0.39)	84.61 (1.00)	90.90 (0.59)	100 (0.00)	100 (0.00)	100 (0.00)
	Debt to income (DI)	1.6 (0.76)	2 (0.43)	1.07 (0.21)	1.07 (0.21)	0.83 (0.15)	0.33 (0.03)
	Wealth (saving status) (SS)	6 (0.94)	15.38 (0.85)	18.18 (0.82)	20 (0.80)	0 (1.00)	100 (0.00)
	Unemployment (UM)	86 (1.00)	84.61 (0.98)	81.81 (0.95)	80 (0.93)	66.66 (0.78)	0 (0.00)
	Life expectancy for shrimp farming (LEI)	0.44 (0.77)	0.61 (0.00)	0.53 (0.38)	0.40 (1.00)	0.51 (0.46)	0.46 (0.69)
	Natural reservation (NR)	0 (1.00)	0 (1.00)	2 (0.33)	3 (0.00)	0 (1.00)	0 (1.00)
	Frequency of occurrence (FO)	2 (1.00)	2 (1.00)	2 (1.00)	0.66 (0.00)	2 (1.00)	2 (1.00)
	Vulnerability index	**0.727**	**0.689**	**0.530**	**0.474**	**0.533**	**0.311**
Resilience	Warning system (WS)	0 (1.00)	0 (1.00)	0 (1.00)	0 (1.00)	0 (1.00)	0 (1.00)
	Emergency service (ES)	0 (1.00)	0 (1.00)	0 (1.00)	0 (1.00)	0 (1.00)	0 (1.00)
	Recovery time after floods (RIF)	46 (0.32)	46.15 (0.32)	68.18 (0.00)	60 (0.12)	0 (1.00)	0 (1.00)
	Flood insurance (FI)	1 (1.00)	1 (1.00)	1 (1.00)	1 (1.00)	1 (1.00)	1 (1.00)
	Vulnerability index	**0.831**	**0.831**	**0.750**	**0.780**	**1.00**	**1.00**
Total social vulnerability index		**0.828**	**0.825**	**0.715**	**0.625**	**0.736**	**0.437**
Rank		**1**	**2**	**4**	**5**	**3**	**6**

Remarks: [1/]The results shown in each column for a district are the value of each proxy variable, together with the normalized value, presented in parenthesis.

Source: Questionnaire survey (2013).

Table 4.8 Social vulnerability index in the district level.

District	Exposure	Susceptibility	Resilience	Vulnerability Index	Rank
Ban Pho	0.927	0.848	0.761	0.845	1
Bang Khla	0.957	0.653	0.665	0.758	2
Khlong Khuean	0.865	0.575	0.800	0.747	3
Muang	0.620	0.428	0.824	0.624	~~6~~ 5
Ratchasan	0.676	0.490	1.000	0.722	4
Bang Nam Priao	0.000	0.430	1.000	0.477	~~5~~ 6
Standard deviation	0.357	0.161	0.134	0.129	

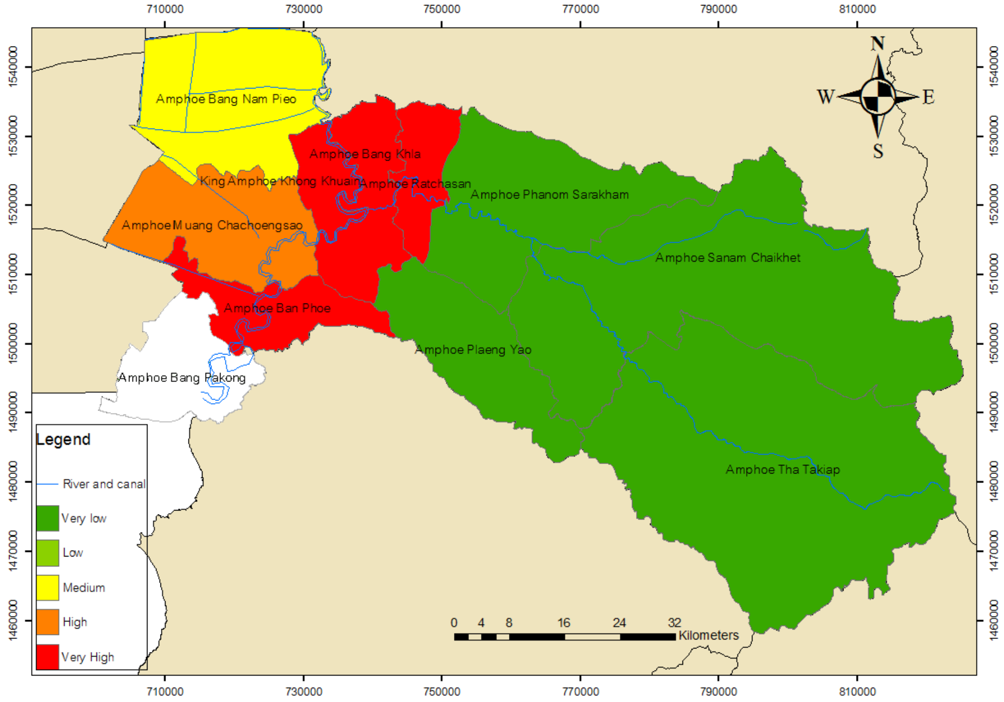

Figure 4.9 Social vulnerability by district in Chachoengsao province.

4.2.3 Composite vulnerability indices

Physical vulnerability can be represented as the vulnerability of the physical environment, while the level of social vulnerability is subject to the adaptive capacity of system to adapt in association with impacts from natural hazards. On other hand, a hazard may cause no or minimal damage to a well-adapted system.

In study, a map of current vulnerability was developed, integrating both physical and social vulnerability. According to scenario analysis, two different sets of events resulting in accumulated rainfall over 10 days between 250-300 mm or exceeding 300 mm were used to project the physical vulnerability map, as these amounts of rainfall were recognized as the thresholds for flash floods in the study area. The first scenario illustrates the extent of inundation that is likely to cause a damage when accumulated rainfall over 10 days reaches 250-300 mm (Figure 4.10).

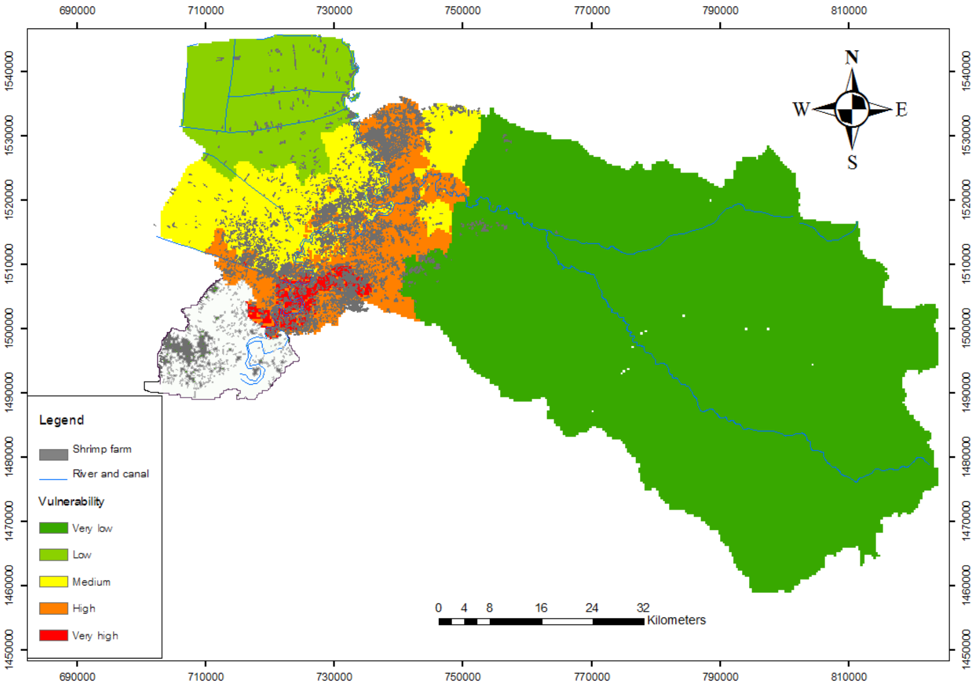

Figure 4.10 Current area of shrimp farming vulnerable to flooding under the scenario of accumulated rainfall over 10 days ranging between 250-300 mm.

The amount of rainfall over 10 days was considered based on the 30 year-average in September. The second scenario represents the worst case of flooding under the influence of rainfall greater than 300 mm, approaching typhoon levels in Chachoengsao province (Figure 4.11). The records of accumulated rainfall caused by Tropical Storm Gaeme during September 16th-25th, 2012, were referred to as the worst case scenario. Figure 4.10 and Figure 4.11 show that almost all of the shrimp farms in the study area are located in areas classified as highly or very highly vulnerable to floods, especially when the accumulated rainfall over 10 days is greater than 250 mm, which is caused by prolonged periods of heavy rainfall and/or the influence of a typhoon. If there is no improvement of the socio-economic characteristics of the shrimp farmers, the flooding situation may worsen in the future.

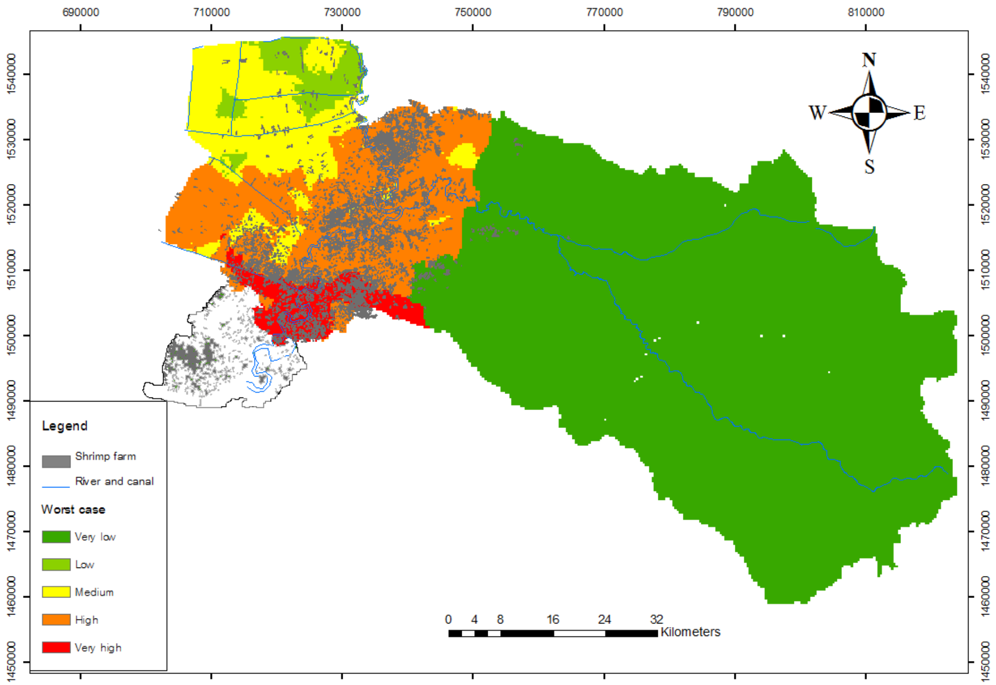

Figure 4.11 Areas of shrimp farming vulnerable to flooding under the scenario of accumulated rainfall over 10 days greater than 300 mm.

4.3 Future vulnerability scenario

Climate projections and future flood vulnerability maps were taken into consideration in this assessment. The results of climate projection over the study area carried out by (Chula Uniresearch, 2011) were adopted for future vulnerability assessment. Based on the research literature on global weather forecast information conducted by using GCGM2, HadCM3, MRI and PRECIS:ECHGAM4 as well as advanced statistical modeling of ASD based on A2 and B2 scenario, the accumulated annual rainfall in the next 30 and 60 years is not predicted to be different under two sets of conditions in the future (national balanced growth development and changes in development combined with a natural treatment). The number of rainy days and the amount of rain over the next 30 years were projected to not differ considerably from the current climate variables. Although the number of rainy days was projected to increase slightly, by 5-10 days, in the next 60 years, the climate in terms of occurrence and intensity of rainfall tended to change from the past especially it is convincible that average temperature and rainfall in Thailand began to be affected from world climate change since 1995. Other physical indicators, such as the slope, drainage density, soil texture, land use, and basin size, are also assumed to remain consistent over the next 30 years, unless the susceptibility and adaptive capacity of shrimp farmers can be modified and improved to reduce future vulnerability. The rising sea level induced by climate change could also affect the hydrological regime of the Bangpakong River. A rising sea level was identified as the most disruptive factor affecting the discharge of flood waters into the Gulf of Thailand. Hence, floods will become more frequent and severe. In addition, the projected vulnerable map under the future scenario is expected to remain the same.

Current vulnerable level of shrimp farms in Chachoengsao province to flood was increased when vulnerability index covered all determinants of vulnerability: exposure, susceptibility and resilience of each district of Chachoengsao province have been taken into account. Not only the physical characteristic in geography of Chachoengsao province is vulnerability to flood, but vulnerability index resulted from the questionnaire survey was also worst. However, the future vulnerability in a short-term scenario 30 from 2011-2040 and a medium term scenario 2040-2069 analyzed by using forecasted amount of rainfall from literature was showed that the exposure caused the flood will not make a worst than current vulnerability. To reduce the future vulnerability, susceptible and adaptive capacities must be taken into account. In fact, shrimp farmers have planned for adaptation options to be employed for coping with floods and these plans have been proved their effectiveness, but the long-term investment budget hinders the decision making of shrimp farmers.

4.4 Establishing adaptation practices

4.4.1 Analysis of adaptive practices and capability

Adaptive practices and capability are essential elements for vulnerability assessments (Kapetsky, 2007). The detailed vulnerability assessment on adaptation practices focused on shrimp farmers who were flood victims. The questionnaire conducted in the study area showed that 100% of interviewed shrimp farmers suffered from the severe flooding in 2011. These farmers experienced flooding in 2011 and 2012. Table 4.9 summarizes the adaptation practices undertaken after the shrimp farmers experienced the 2011 flood to cope with later floods (e.g., the 2012 flood). The practices were implemented after the 2012 flood warning by the Sub-district Administration Organization and Chachoengsao Provincial Fisheries Office. In terms of the adaptation capability, the majority of shrimp farmers were able to implement adaptation practices to prevent the negative effects of flooding and the loss of shrimp production. However, approximately 19.4% of the total interviewed victims (small-scale shrimp farmers) did not implement adaptation practices due to budgetary constraints.

Table 4.9 Adaptation practices undertaken to eliminate or reduce the impact of floods.

	Shrimp farmers in Chachoengsao Province (n=109)		
		% impact reduction	
Adaptation practices	% of interviewees	% of responses for complete reduction	% of responses for partial reduction
Practices to eliminate or reduce the effects of floods			
Placed a net around the pond to prevent the escape of shrimp	57.2	12.6	37.8
Increased the height of the dike surrounding the shrimp pond to 0.3-1 m above ground level	66.9	28.1	33.9
Harvested shrimp early	31.0	9.7	21.3
Practices to prevent flooding			
Changed timing for culturing the shrimp	6.7		
Obtained relevant information on flood occurrence from supporting agency/database	28.1		

Remark: The percentage of impact reduction was not taken into account for practices that prevented flooding because these activities were performed prior to the flood.

Source: Survey data (2013)

The adaptation practices implemented by shrimp farmers to prevent and reduce the effects of floodwater on their shrimp farm areas are as follows: (i) placing a net around the pond to prevent the escape of shrimp, (ii) increasing the height of the dike by covering it with soil, and (iii) harvesting the shrimp early to avoid the floods. The results reveal that shrimp farmers in all districts greatly affected by the 2011 flood preferred to increase the height of the dike around the shrimp pond. This technique was preferred among the majority of shrimp farmers because the floodwater could not cross the dike and hinder shrimp production. However, these farmers must be able to afford employing an external excavator to create the dike around the pond.

Additionally, one of the most important issues that limit the adaptation capacity at the farm level is the lack of appropriate attention and investments for reducing and minimizing the effects of flooding. The study revealed that even though a financial relief fund was offered to flood-victim shrimp farmers, the relief funds were inadequate to compensate for the losses. The relief fund of the Chachoengsao Provincial Fisheries Office only covered 5-10% of the total cost of the estimated damage. A cost-effective approach would be to re-allocate the funds to increase the adaptability of farmers in advance.

After the severe flooding in 2011, shrimp farmers have been aware of the need to address future floods. A minority of shrimp farmers have employed practices to avoid flood damage via practices such as changing the timing of culturing shrimp (e.g., finishing the rearing of shrimp by September-October) and obtaining relevant information on flood occurrences from institutional agencies and local government offices. However, the questionnaire results showed that shrimp farmers preferred to take a risk even when acknowledging the potential loss of production in the event of a flood. A majority of the shrimp farmers are unwilling to change their regular practices and are reliant on flood warnings from relevant authorities. The farmers are likely unwilling to change the timing of shrimp rearing or stop rearing the shrimp during September-October because most shrimp farmers do not have an alternative occupation to generate supplemental income. Another reason is that a benefit obtained from selling raw shrimp is attractive and much higher than minimum wage work. Even though shrimp farmers want to change career, but they aren’t changing due to lack of qualification and experience in industrial works.

4.4.2 Adaptation options for reducing vulnerability

4.4.2.1 Reduction of social vulnerability

To develop various options for effective flood management, a range of qualitative data was collected using a questionnaire survey to understand the shrimp farmers’ capacity to cope with floods (Dewan, 2013). Current social vulnerability indices were evaluated using 20 indicators, as shown in Table 4.9. The results regarding the social vulnerability index of each district of Chachoengsao province can aid in determining priority areas for treatment. Moreover, the social vulnerability index results can help to identify the keys factors affecting the adaptive capacity of shrimp farmers and increase the effectiveness of adaptive practices. For instance, the social vulnerability index of the Bang Pho district indicated the highest social vulnerability among the 6 districts. The Bang Pho district requires critical attention to support adaptation for future floods. The factors influencing the adaptive capacity to reduce the social vulnerability of shrimp farmers in the Bang Pho district are relevant to wealth, the amount of debt, education level, the size of shrimp farm, and secondary occupations.

To identify the reduction of vulnerability when the susceptibility and exposure of shrimp farmers are modified, we assumed that the shrimp farmers in 5 districts of Chachoengsao province (Ban Pho, Bang Khla, Khlong Khuean, Muang and Ratchasan) showed improved economic levels. Three economic indicators: wealth or saving status, not living below the poverty line, and secondary occupations, were taken into account because these indicators are considered to be highly influential factors in the adaptive capacity. As a result, the total social vulnerability indices for the Ban Pho, Bang Khla, Khlong Khuean, Muang and Ratchasan districts were reduced from the current level of vulnerability shown in Table 4.8 to 0.669, 0.678, 0.572, 0.486 and 0.576, respectively. The degree of vulnerability aggregated between current physical vulnerability and improved social vulnerability under the scenario involving accumulated rainfall >300 mm was projected and is presented in Figure 4.12. Results revealed that reducing the susceptibility and exposure of shrimp farmers through improving their economic status could help reduce vulnerability.

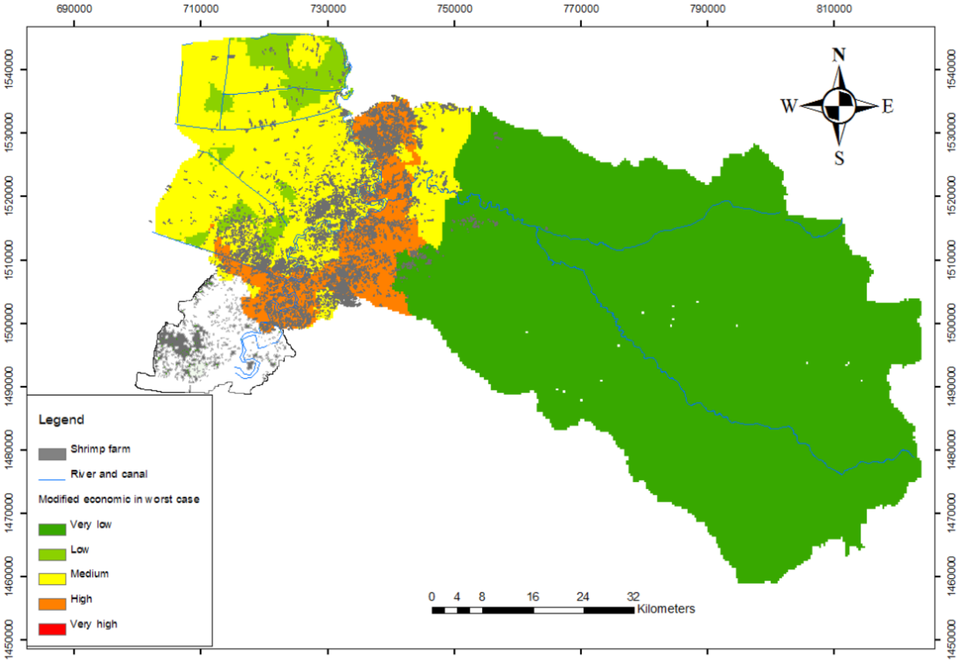

Figure 4.12 Physical vulnerability map under the scenario of accumulated rainfall over 10 days greater than 300 mm after improving the economic status of shrimp farmers.

4.4.2.2 Structural and non-structural adaptation options

The results obtained through interviewing shrimp farmers regarding the adaptation options undertaken to cope with flood events during 2011-2012 and their effectiveness were analyzed. The types of adaptation options implemented by shrimp farmers and their effectiveness for significantly reducing flood damage were analyzed as percentages. The results showed that the existing adaptation options mainly consisted of (i) placing nets around shrimp ponds to prevent the escape of shrimp (12.6%); (ii) increasing the height of dikes by covering the pond surface with soil (28.1%); (iii) early harvesting prior to a flood occurring (9.7%); and (iv) changing the calendar for culturing shrimp (N/A).

The investigation showed that shrimp farmers adopted strategies involving both structural and non-structural options to adapt with flooding. The structural modifications to mitigate flood impacts undertaken by shrimp farmers included the construction of dykes and placing nets around shrimp ponds to prevent the escape of shrimp. However, the effectiveness of the structural techniques was low because they were only partially completed and repetitive losses occurred during the most recent flood events in 2012. The main reasons for these losses were incomplete construction of physical flood protection measures and failure of structural flood protection measures due to an excessive flood depth. The adoption of non-structural techniques, including early harvesting of shrimp prior the occurrence of floods and changing the calendar for shrimp culture, are alternatives for farmers with limited financial resources.

In testing the hypothesis of a relationship between the socio-economic characteristics of shrimp farmers and the implementation of the various adaptation options, only adaptation options involving structural approaches (both dykes and net installation) were tested. Because the socio-economic conditions of shrimp farmers affect their adaptive capacity, improving their socio-economic conditions as a key factor to enhance their adaptive capacity was tested in relation to the most recent adaptation strategies applied to reduce flood damage. Five socio-economic characteristics (education level, wealth or saving status, secondary occupations, farm experience, and farm size) that would affect the adaptive capacity, selected from the total of twenty indicators, were used to evaluate the influence on the decision to increase the adaptive capacity.

The results of the hypothesis test presented in Table 4.10 revealed that five of the socio-economic characteristics: education level, wealth or saving status, secondary occupations, farm experience, and farm size, did not show a significant association ($p < 0.05$) with the decision to apply structural approaches as an adaptation option. This association test was carried out at nominal level using the Chi-square test. This implies that the strategies adopted to address flooding by employing the structural techniques of both placing nets around shrimp ponds and increasing the height of dikes to mitigate the impacts of floods are not directly influenced by characteristics such as wealth, a high level of educated, or farm size. Perception and past experience regarding flooding may be additional factors affecting this decision, beyond social and economic status. Shrimp farmers who own very few shrimp rearing ponds and have a limited amount of money to invest in the implementation of structural strategies demonstrate their intention to make their best effort to prevent serious damage from floods. Loss claims increased continuously over the study period, which appeared to trigger the adoption of structural construction strategies. This finding is consistent with the results from assessing the correlation between the preparedness/awareness of shrimp farmers and the choice of adaptation options for mitigating floods. Preparedness or awareness is also a significant major driver of the adoption of adaptation options ($p < 0.01$).

Table 4.10 Chi-square analysis of the association between the socio-economic characteristics of shrimp farmers and the implementation of adaptation options.

Variables	χ^2 value	Df	P-value	Decision regarding significance
Education level	29.878	30	0.472	Not significant
Wealth	6.603	5	0.252	Not significant
Secondary occupation	6.217	5	0.286	Not significant
Farming experience	69.877	95	0.975	Not significant
Farm size	138.803	165	0.932	Not significant

Remarks: Df – degrees of freedom; χ^2 – Chi-square value

Source: Questionnaire survey (2013)

Based on the consequence of hypothesis testing, improving the effectiveness of structural approaches for flood management is a critical component for reducing the impacts of flood events. Information on the depth and speed or flow volume of floods appears to be necessary to increase awareness and improve the effectiveness of existing structural practices. Practical knowledge regarding the implementation of structural measures is required. For instance, shrimp farmers who are well educated and wealthy still do not prepare themselves sufficiently for flood events, even though structural mitigation techniques are employed. Incomplete prevention has resulted from the fact that height of dykes has not been sufficient to prevent overflow due to flooding, and large volumes of rapidly flowing flood water have caused damage to nets. Nevertheless, in addition to accurate flood forecasting in term of flood depth and the volume of flow, the provision of financial resources is still necessary to assist shrimp farmers who have a limited capacity for implementing mitigation options.

Utilization of the vulnerability map combining the physical and social vulnerability indices could be adopted to a greater extent in the proactive planning of adaptation measures among decision makers and local shrimp farmers. Thus, improvement of both the socio-economic conditions of shrimp farmers and the effectiveness of structural approaches should be carried out coherently. Furthermore, non-structural approaches for managing flood risks could be a good alternative as adaptation strategies, as they would certainly be less expensive than structural approaches.

4.5 Flood risk mapping

In this study, an attempt has been made to assess the flood hazards in accordance with the past flood experiences before integrating with the vulnerability map. The highest score of likelihood (5) was given to districts that have been flooded every time when floods occur in Chachoengsao province. Meanwhile, score of likelihood of three and one are given for likely and possible hazards, as presented in the Table 3.8 of Chapter 3. Even though there is no shrimp farm in Sanam Chaikhet and Tha Takiap district, both districts were included in this assessment.

The aggregate score, obtained by combining the likelihood and potential damages when accumulated rainfall for 10 days is greater than 250 mm, provides the basis for a risk ranking separated into four categories including: extremely high risk, high risk, medium risk, and low risk (Table 4.11). Flood risk map was, then, built in combination of vulnerability map with the probability of the flood event resulted in the Table 3.8 of Chapter 3. As a result of flood risk shown in Figure 4.13, an estimate of the plausible number of shrimp ponds and areas at risk of flooding was ultimately determined and summarized in Table 4.12. The results indicated that 41.49% and 32.61% of total number of shrimp ponds in the study area are exposed to extremely high and high risk, respectively. In term of coverage, 43.63% and 30.63% of shrimp farm areas were exposed to extremely high and high risk, respectively. These shrimp farms should be considered as the top priorities in flood mitigation and planning.

Table 4.11 Estimated risk score for each flood risk category.

Estimated risk values	Risk level/scale	Further actions
>18.75	Extremely high risk / 4	Immediately action required
12.5-18.75	High risk / 3	Action plan required
6.25-12.5	Medium risk / 2	Specific monitoring and/or procedures required
< 6.25	Low risk / 1	Manage by routine procedure

Remark: Estimated risk value is the product of hazard (highest score 5) and vulnerability (highest score 5)

Table 4.12 Estimated of the number of shrimp farms and areas at each risk dimension.

Description	Risk level				Total
	Extremely high risk	High risk	Medium risk	Low risk	
Number of shrimp pond (pond)	11,894	9,349	1,652	5,771	28,666
Area of shrimp farm at risk (ha)	4,387.68	3,080.48	557.44	2,030.4	10,056

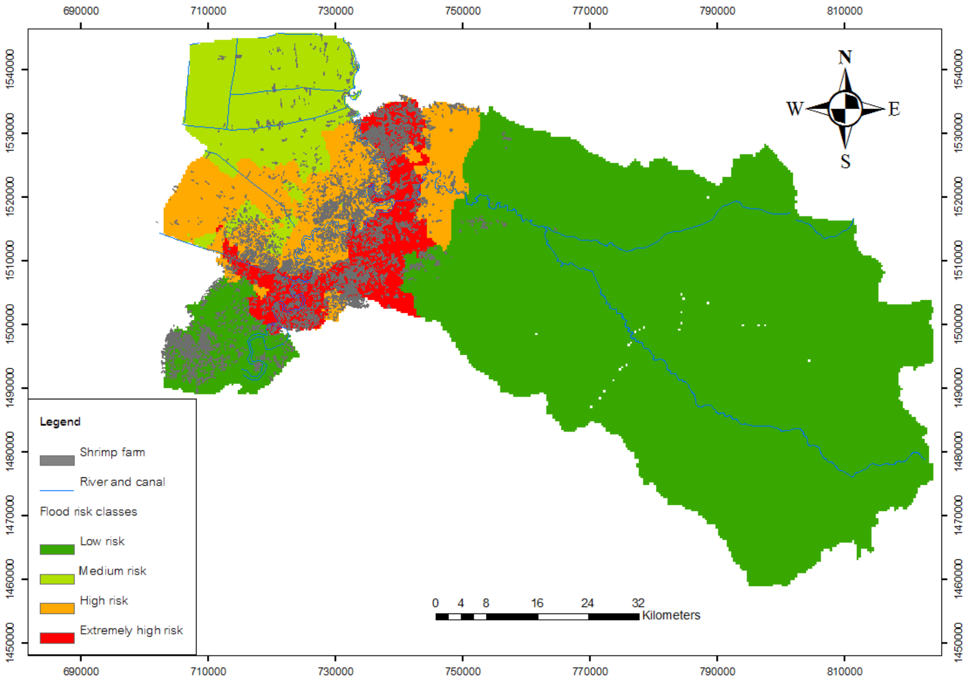

Figure 4.13 Flood risk map over shrimp farms located in study area.

4.6 Economic analysis

4.6.1 Estimated damage costs

The exposed farmed shrimp in each district are classified into 2 classes (maximum and minimum damage cost) and are derived from the flood vulnerable area map, representing the high and very high vulnerability of future scenario in the next 30 years overlapped with the shrimp farm areas. For assessing the change in estimated damage cost due to socio-economic development, this concern was also taken into consideration for developing the flood vulnerable area map. Table 4.13 showed that estimated maximum damage cost, which calculated from the shrimp attain the market size (60 pieces per kilogram) on affected shrimp farms in each district were range from 0.17 to 16.06 million USD. Meanwhile, minimum estimated damage cost assumed from the damage since the first day of releasing shrimp fry from mixing of pacific white shrimp and giant freshwater prawn at ratio 50,000:6,000 into pond sized 1 rai (0.16 ha) were range 0.04 to 0.45 million USD.

Table 4.13 Maximum and minimum damage cost on farmed shrimp in each district (USD).

District	**Maximum estimated damage cost**^{1}	**Minimum estimated damage cost**^{2}
Ban Pho	16,068,125	454,725
Bang Khla	15,367,281	434,891
Khlong Khuean	7,512,703	212,608
Muang	170,938	4,838
Ratchasan	2,564,063	72,563
Bang Nam Priao	2,307,656	65,306

Remark: $^{1/}$Pacific white shrimp price at 227 Baht (7.09 USD)/60 pieces per kilogram, while giant freshwater prawn price 400 Baht (12.5 USD)/50 piece. Survival rate at 60% was also used to estimate the damage cost

$^{2/}$Price of pacific white shrimp fry equal to 0.12 Baht (0.00375 USD), while giant freshwater prawn equal to 0.29 Baht (0.009 USD)

According to the flood risk map; moreover, approximately 75% of shrimp farms are expected to suffer from flooding every two years or 50% annual chance of flooding (1-in-2). Unless heights of dike ponds are raised sufficiently, flood waters will overflow and cause damage to the farms. It is clear from the experiences and visits to local shrimp farms that heights of pond dikes are currently not adequate. Therefore, damage cost was estimated for all shrimp farming areas that are located in extremely high and high risk to flood. The estimated damage costs for the whole risk area of shrimp farms would imply economic losses as occurred in flood year when there is inaction and no investment for adaptation. Based on the results from the table 4.14, shrimp farms that are located in the extremely high and high risk zone are considered to have a greater than 50% annual chance of flooding (1-in-2). Meanwhile, shrimp farms located in medium risk areas especially in the Bangpakong district will have annual chance of flooding of 20% (1-in-5). Then, total damage costs were estimated and compared between two flood events of 20% annual chance of flooding or 1-in-5 and 50% annual chance of flooding or 1-in-2.

Damage cost estimation was separated into two scenarios; 1) losses of income from damages of market-size shrimps (maximum damage cost scenario) and 2) floods has overflown shrimp farms in the first day of releasing shrimp fry (minimum damage costs scenario). As shown in the Table 4.14, the results revealed that estimated maximum damage cost in each flood risk category ranges between 437.58 - 589.21 million USD. The estimated minimum damage cost (with shrimp fry mixing of pacific white shrimp and giant freshwater prawn at a ratio 50,000:6,000 in pond size of 1 rai (0.16 ha)) ranges from 11.28 to 15.20 million USD. In summary, damage costs between 11.28 and 437.58 million USD is expected to happen every two years event if there is no implementation and or improvement of adaptation. On the other hand, the damage cost can become benefit if flood protection measures are implemented and can completely prevent the damage on shrimp production. The results also help indicate where the focus should be in reducing the flood risk and vulnerability on shrimp farms.

Table 4.14 Maximum and minimum damage cost on farmed shrimp in each chance of flood event.

Unit: USD

Flood event (annual probability)	No. of shrimp pond at risk (pond)	No. of shrimp area (ha)	Maximum estimated damage cost	Minimum estimated damage cost
0.5	21,243	7,468	437,587,500	11,289,758
0.2	28,666	10,056	589,218,750	15,201,844

4.6.2 Cost and benefit analysis of measures used to prevent the damage by floods

Direct tangible costs for two structural flood control measures (e.g. construction of dike and maintenance costs over the life-time) were calculated using results from the questionnaire survey and in-depth interview. Other costs associated with non-structural flood control measures were also included in the analysis. These costs were adopted from and the results of in-depth interview with the farmers experienced flood. For instance, annual maintenance costs for maintaining dike height is equal to 50% of the initial construction cost and remain the same every year for the next 50 years. For netting around the pond, net's useful life would normally be shorter than the dike construction measure. Based on the survey result, nets could be used only once before they need to be replaced. This is due to many reasons such as damages from high flow velocities, damages from various objects, and losses of nets under massive flooding condition. Therefore, new investment on nets was observed in associate with annual probability of occurrence.

As shown in Table 4.15, opportunity costs which is the cost of forgoing the next crop is ten times higher than costs for newly construction of the dike and seventy-five times higher than costs of purchasing nets. This result illustrates why shrimp farmers do not want to shift to the next crop calendar and prefer to take flood risks even with the potential loss of production. When all shrimp farms that are located in extremely high risk and high risk area to flood are assumed to start investment for flood structural control measures, the first year of investment costs for dike construction and purchasing the net over the whole study area are 7.46 million USD and 0.93 million USD, respectively.

Table 4.15 Costs for different flood adaptation measures per shrimp pond sized 1 rai or 0.16 ha.

Unit: USD

Measures	Construction costs and/or opportunity cost	Annual maintenance
Dike height increase[1/]	1,000	500
Netting around the pond	125	125
Early harvesting	3,750[2/]	-
Shift crop calendar	9,375[3/]	-

Remark: [1/] This cost was estimated from the employment of external excavator for 2 days (2,000 Baht or 62.5 USD per hour)

[2/] Average 60% loss from the total benefit is a result when early harvesting was conducted

[3/] 100% loss from the total benefit is expected when forgoing one crop of production

Resource: Questionnaire survey (2013)

4.6.3 Sensitivity analysis

In understanding model characteristic, one of the simple tools normally used is sensitivity analysis. In this study, sensitivity analysis is used to define the robustness of a model. Sterman (2000) explains that the analysis involves changing one or more variables to assess changes of the model's output. An assessment the robustness of the model is required to compare the output before and after changing variables. This is the way to make the model robust and consequently more reliable for policy-making.

Nevertheless, neither social vulnerability indicators nor physical vulnerability indicators were analyzed the sensitivity in order to identify the effects of changes in the value of tested variables. The reason is that physical characteristic changes are not likely to be happened in the next 50 years even though physical characteristic changes usually result in changes of flood pattern through impermeable rate and runoff direction. Meanwhile, value of each social vulnerability indicator was reflected from the consequence of the questionnaire survey. It is not required to change the tested values ranging to particularly ± 10% of current values.

In the analysis, two structural flood control measures (dike height increase and netting around the pond) were considered in an estimation of avoided flood damage costs. In order to test the robustness of the results, a sensitivity analysis was performed assuming that some small-scale shrimp farmers may not be able to adapt and invest for structural flood control measures and/or the flood structural measures are ineffective. From the survey results, we found that approximately 20% of shrimp farmers cannot afford the cost of the measures because they are very poor. The survey also identified that approximately 20% of the measures are ineffective. This information was used for sensitivity analysis. It is; however, important to note that estimated annual benefits from structural flood control measure do not consider the risk of failure of the measures, which can occur due to a variety of reasons including inadequate maintenance and severity of flood itself.

Table 4.16 presents the estimated annual benefits (not yet subtracting the expenditure costs for each structural measure) for different return period of flood event throughout the project life of 50 years. The results reveal that shrimp farms that have increased the dike height will receive benefits higher than that of netting around the ponds. The effectiveness of each measure to prevent and reduce losses of future flood is the main factor contributing to the difference in the value of damage avoided. Results from in-depth interview showed that if the dikes are built adequately, it could completely eliminate flood damage on shrimp production. Total avoided damage costs or benefits over the study areas, in this case, will increase by more than 110.27 million USD for the lifetime of 50 years or equal to 9.18 million USD annually. As we are dealing with the probability; however, the adaptation measure should be considered in the light of flood event's return periods. The majority of shrimp farms in extremely high risk zone may be prioritized as the first target to gain the benefits from damage avoided by applying structural control measures. While non-structural flood control measures may be suitable for some shrimp farms in medium risk category and lower or that of higher return period events.

Table 4.16 Annual benefit or damage avoided from structural flood control measures in different return period of flood event.

Unit: Million USD

Measure	Return period of flood event (annual probability)	Annual benefit (damage avoided)
Dike height increase	1-in-2 or 0.5 annual probability	280.05
	1-in-5 or 0.2 annual probability	377.10
Netting around the pond	1-in-2 or 0.5 annual probability	196.03
	1-in-5 or 0.2 annual probability	263.97

It is important to note that annual benefits or avoided damages is for only one crop a year even though a maximum of four crops a year is reported. In addition, the net benefit for one crop a year and cost of the different structural control measures was carried out for the two discount rates of 2.7% and 4%. The results as illustrated in Table 4.17 indicate that the B/C ratio is higher than zero for all measures throughout the lifetime of each measure. It also reveals that the B/C ratio for putting nets around the ponds at a discount rate of 2.7 is higher than increasing dike height. This result implies that putting nets around the ponds which requires less investment is an attractive alternative measure for shrimp farmers who lack sufficient financial means.

Table 4.17 Economic pay-off from investing in structural flood control measures for pond sized 1 rai (0.16 ha).

Measure	Discount rate	Present value of benefits (USD)	Present value of cost (USD)	Net present value (USD)	Benefit-cost ratio
Dike height increase	2.7	28,128	7,816	12,398	3.60
	4	22,226	2,810	10,928	7.90
Netting around the pond	2.7	19,618	3,533	10,031	5.55
	4	15,486	2,810	7,089	5.51

On the basis of the results of this study, I summarized that the current flood vulnerability of 6 districts in Chachoengsao province, and expressed as estimated annual damage costs even minimum damage cost, which is started from 7,740 Baht per pond 1 rai (0.16 ha), was nearly closed to the costs invested for structural measures. Using information on the estimated damage associated with the probability of occurrence projected to the next 50 years, was used to estimate the costs and benefits using data collected from the questionnaire survey and flood vulnerability map. Results of cost and benefit analysis implies that costs for construction of structural much lower than opportunity costs, which is associated with the net return from shrimp production for one crop. As benefits are a lot of higher than costs, it was the reason that all of shrimp farmer have decided to take a risk of flood without any mitigation measures. Structural measures were found to be economically viable. In the case of increasing the height of bund and putting the net around pond, the benefit-cost ratio ranged from 3.6-7.9 depending on the discount rate used in the analysis. It is therefore recommended that the shrimp farmer should improve their structural measure to prevent the damage from flood. Government decision maker should also consider the way to improve the adaptation capacity for the shrimp farmer such as provide the loan and educate the local shrimp farmer on the risks associated with flood and development of an effective flood advisory system. However, the effectiveness of each structural measure is subject to the inundation depth and velocities of floodwater. This information should be further analyzed in order to encourage shrimp farmers to construct the flood structural measures more accuracy.

4.6 Policy implication under current condition

To draw out policy implications based on the model’s output, results based on current condition was explored. Drawing of policy implication was included the finding on the current vulnerability level, sensitivity results and results of proactive adaptation undertaken to combat with last flood events. Not only policy implication on the study area but also other provinces that were badly affected by floods was taken into account for drawing policy implication. The following are the results of policy implication for both areas

4.6.1 Policy implication for study area

The model output indicates that the shrimp farmers who were victim from the last flood events have difficulties in their career to cope with the floods. The model output for vulnerable area of shrimp farm to floods show that almost shrimp farms are likely will be encountered with floods, which will occur at every two years basis. Floods can completely flush away of shrimps that are reared in the pond if there is no measure to prevent the loss from floods. Over time, the floods have changed shrimp farmer's cultural approach to their farming system. The floods also interrupt shrimp farmer's activities especially the number of crop for shrimp production has decreased from three crops to one-two crops instead.

Although the floods disrupt shrimp farmer's activity and cause of loss of income, they prompt reactive response. Responses from interviewed shrimp farmers highlights that roles of past floods could influent variables of local knowledge, economic status enhancement and government's capacity. The rural relationship of my case study partly explains the response to the floods. They have exchanged their knowledge and experience how to combat with flood through strong social networks among shrimp farmers. Both the past experiences of floods and the high awareness from the loss are reflected in several actions to cope with upcoming floods either structural measures or non-structural measures. Since of all these are initiated by the shrimp farmers in the event of a flood, these actions are considered as reactive adaptations.

The reactive adaptations used to face of threatening situation are not adequate as flood disaster responses. In particular, most of measures used to combat with the past floods could not prevent the damage from floods. Therefore, more proactive and integrated reason learns from the failure operation are needed to improve the shrimp farmer's responses to floods. Within shrimp farmer's responses, proactive forms of adaptation can be drawn by government and external parties. Conversely, the proactive adaptation should be firstly initiated by the government and external parties.

As from the social vulnerability assessment, the past flood experience and economic conditions of shrimp farmer were resulted in maximum performances in selected measures to response the probability of flood. It means that shrimp farmers have initiated to apply proactive adaptation, but many barriers have limited their ability to apply proactive approaches. The results of improving the quality of government where responsible on disaster prevention unites and provide sufficient information to shrimp farmers on adaptive measures are one of the most important elements in improving flood disaster response in my case study. On the other hand, it also shows that the current response level of the government to flood is not sufficient.

Based on the results on study of current condition, improving shrimp economic conditions, flood warning information and guideline to improve current structural measures are necessary. The involvement of external parties on these concerned can reduce the vulnerability level. This result was in consistency with the model of vulnerability level when adaptive capacities were modified. The level of vulnerability only changes the variables for *wealth (saving status)*, *unemployment* and *warning system*. Therefore, the improvement of socio-economic condition should be supported by an improvement in government capacity.

Figure 4.14 shows strong link between government involvement and external parties for convincing evidence of their important with variables in flood risk management in my study area. This diagram was developed based on the variables that could significantly reduce the vulnerability level of the study area.

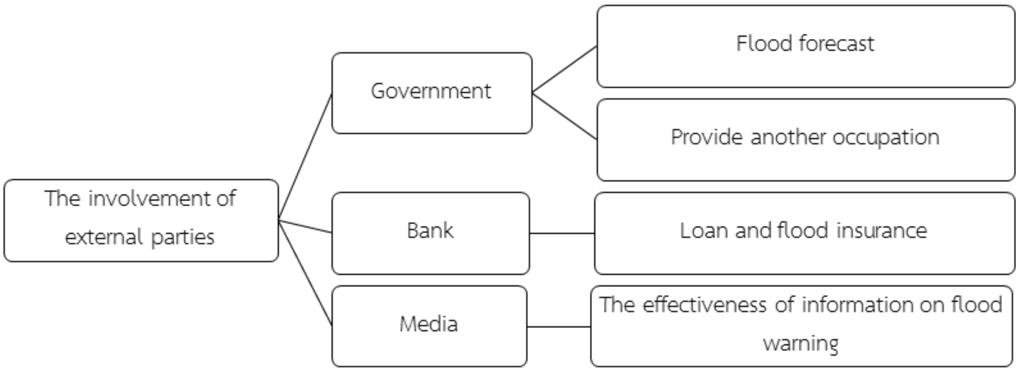

Figure 4.14 A diagram for the involvement of external parties for flood disaster management.

Obviously that social vulnerability to floods can be reduced by introducing economic-related adaptations. Based on diagram provided above, one key informant asserted the importance of economic approach is to provide a better source of extra income. The extra income is important in particular for the situation where shrimp farmer have no saving or under poverty line. Currently, majority of shrimp famers have no extra income. Very few interviewed shrimp famers have another career i.e. grocery shop and company's employee, but they don't have saving. Therefore, the main reason for reduction of the vulnerability is also increasing shrimp farmer saving. Loan provided by bank is rapid way to get shrimp farmer's hand with some cash for applying adaptive measures. This is primary requirement for shrimp famer before starting the investment of adaptive measures especially structural measures. The increase in income will immediately increase ability of shrimp farmers to construct and employ the structural measures. On other hand, increasing of income will also increase both the economic and the level of spending. For post flood event, the flood insurance will instantly cover or compensate shrimp farmer's loss of shrimp production. However, this is less attractive observed during the site survey because relief fund provided by Department of Fisheries is still available for damaged shrimp ponds. In conclusion, boosting economic of shrimp farmer is needed to be accompanies by other mechanism especially from bank.

The improvement of structural measures include increasing the height of dike and netting around the pond can also significantly reduce vulnerability and risk of shrimp farms to be inundated by floods. It is because of they can significantly decrease the probability of shrimp to be washed away by flood. As long as shrimp ponds are not overflown by floods, shrimp farmer will not loss their shrimps reared in the pond and loss of income. However, the effectiveness of improved structural measures is lower when facing with high floods compared to the averaged flood depth. These two adaptations are also the most preference measure for adaptations assessed. For the better structural measure construction, it is clear that the adaptation is only effective for well-being shrimp farmers. Meanwhile, majority of shrimp farmer in the study area which are small scale shrimp farmer have low income and will be in a worse situation than those well-being shrimp farmers or industrial shrimp farmer.

For relocation in particular, the results from the site survey reveal that it is less attractive choice for shrimp farmers. Even though this practice is most significant reducing the flood impacts on the highest vulnerable shrimp farms, it is not likely to happen in my case study area.

Based on the explanation above mentioned, the success of every adaptation will always depend on economic status of shrimp farmers and its effectiveness of structural measures in minimizing the inundation height. However, not only adaptive measures required to have good economic, but also non-structural measures can be applied. These measures do not required improving of economic, but still do require involvement of external parties to provide sufficient information in particular flood forecasting information and flood warning. As the study was also analyzed on the chance of flood occurrence, the shrimp farm areas that will not be affected by flood in every two years should apply non-structural measures such as early harvesting prior to a flood occurring and changing the calendar for culturing shrimp particularly during September of each year.

Moreover, lessons from the past floods could incorporate into water management. Unfortunately, there is no the flood and water management act in Thailand. However, James (2005) indicate that there has been a clear evolution from thinking in terms of water control to water management. This is because of the forces of natures are so strong and we cannot control water with complete certainly of outcomes. Passively accept what water imposes on society is however certainly realized by all parties concerned, but prevention or mitigation the threats posed by nature or even transform them into benefits by judicious management of water resource is still required.

4.6.2 Policy implication of shrimp farms in other provinces

4.6.2.1 Awareness of change in climate and flood risk on other farmed areas

Flooding is considered one of important natural problems influenced by climate change. Among many provinces which experienced severe flooding are included provincial shrimp farming production. Meanwhile, investigation the potential impacts of climate change on future floods in Thailand were recently aware among stakeholders. Possibility of frequency and intensity of floods for wet season is expected to be increased for the entire country which was divided into nine Hydrological Response Units (HRUs) (Shrestha, 2014). This result was slightly different with results conducted by Kuntiyawichai (2011) for the Mekong, Chi, and Mun River Basins showing the results obtained from statistical downscaling method using the climate simulation given by the UK HadCM3 model under A2 and B2 scenario. In general, the projected trends of rainfall characteristics were found to be consistent with the observed historical trends. However, the concern on the future flood has not taken into account adequately for shrimp farming to prevent the damage by floods. The need for flood risk mapping and shrimp farming zoning strategies is strongly recommend.

Over the past decade shrimp farmers in Thailand have observed increasing the risk to flood. Some provinces were suffered by flood every year during to monsoon season such as Surat Thani, Nakhon Si Thammarat, Trang, Chumporn, Songkhla Chachoengsao, and Prachinburi (Table 4.18). Flood condition remained in some shrimp farms in some low-lying areas. At the beginning heavy rains occurred across northern part of Thailand and mountains in the southern provinces, before flood waters and/or water runoff began to the floodplain areas with shrimp farms. This synthesis is consistent with the results from the dissertation focused on Chachoengsao province showing that accumulated rainfall above the threshold is the major causative of flood occurrence in all shrimp farm areas. In addition, shrimp farms located in the lowest floor in relation to the elevation are required to have the flood risk map. There is however no development of the flood risk map for shrimp farming until now even though shrimp production which is major part of agricultural production could contribute Thailand's GDP of 8.3 for year 2013 (BankofThailand, 2014).

Table 4.18 History of flood events in each province where culture shrimp.

Number of past flood events in 2005-2013	Provinces	Flood event (time/year)	Annual probability	Historical flood hazard
>4	Chachoengsao, Suratthani, Ranong, Prachinburi, Songkhla, Chantaburi, Chumporn, Nakhon Si Thammarat	1-in-2	0.5	Very highly likely
>1 to ≤4	Chonburi, Yala, Phang nja, Phuket, Krabi, Trang, Rayong, Trad, Prachub Khiri Khan,	1-in-5	0.2	Likely
≤ 1	Pattani, Samutsakorn, Samutprakarn, Petchburi	1-in-8	0.125	Possible

Local knowledge of imminent extreme precipitation caused by monsoon would be useful to adapt better to current climate whether it was changing or not. However, awareness of increasing of probability of flood occurrence seems to be less than the benefits obtained the ability to avoid the damage by flood (avoided damage cost). Even though the flood relief fund spending by Department of Fisheries and that these estimate are less than the actual damage cost, but the shrimp farmers who were experienced on flood several times are still prefer to take the risk because the benefits obtained from avoiding flood is attractive.

4.6.2.2 Flood impacts on shrimp farming

Thailand is the one of world's leading exporter of shrimp worth 96,791.61 million Baht with approximately 25 percent of world market share, and employing more than 1 million people with approximately 362,645 rai of land are used for shrimp farming (Thailand Frozen Food Association, 2011; WorldBank, 2012; Fisheries

Information Technology Center, 2011). Currently, Fisheries Information Technology Center (2011) revealed that there are only 24 provinces in Thailand that can culture both shrimp and fish. With the loss of production throughout the duration of the floods led to interception of the global supply chain for Thailand agricultural products (WorldBank, 2012). In particular, as a consequence from the research by Muralidhar (2010) revealed that severity of flood overflown shrimp ponds caused hundred percent of damage to cultured shrimp because shrimps are suddenly washed away be the flood.

Four main types of natural flood occur in Thailand: flash floods, river floods, rainwater floods, and coastal floods induced by storm surge. However, flash floods which usually begins in low-lying areas during the monsoon months of June-September (Benfield, 2012). Run-off during exceptionally heavy rainfall occurring in neighboring upland areas is cause of the flash floods. Such floods occur as waters from the upstream rush to the plains with high velocity, and destroying physical infrastructure. Shrimp farms located in southern provinces of Thailand were frequently experienced seasonal flash flood caused by heavy rain and run-off from the mountains, but the duration of flash floods may inundate a floodplain several times during a single month. High velocity floodwaters have caused damage to structures of shrimp farms especially the farm bund and net that putting around the pond even though the flash floods are occurred in the short term event. Not only maximum damage costs with regard to when shrimps attain the market size escaped from the flash floods, but also the costs for repairing or replacing infrastructures are reason to make the damage costs from flash flood caused by run-off worsen than other floods.

Meanwhile, flooded water seems to be moving slowly to inundate shrimp farms located in central and eastern provinces. However, the average duration of the floods recorded since 2005 is about one and half month. Long period inundation had significant changed on water quality in culture ponds and effect to survival and yields of shrimp because TN (total dissolved nitrogen), TP (total dissolved phosphorus), COD (chemical oxygen demand), and DOC (dissolved organic carbon) contents during the flood period were significantly higher than those during the ebb period (Wang, 2010). Shrimps that are not immediately escaped after a flood will be shocked and dead because shrimp are very sensitive to quickly changing water conditions. Therefore, there is no difference between effects to cultured shrimp that inundated within a short period of time and effect from overflow by huge volume of flooded water caused by run-off. Moreover, the unnatural feeds, hormones and excessive quantities of antibiotic used on other shrimp farms and factories can have a great impact on the shrimp farm industry in Thailand if shrimps that were exposed to these undesirable substances were harvested and exported to US and EU countries.

Based on the results from the previous analysis on cost and benefit, if 5% of shrimp areas from total shrimp farming areas of 362,645 rai were flooded, the estimated damage cost when shrimps attain the market size would be 5,439.67 million Baht. This cost is expected to be happening in every single year if counter measures to prevent the damage by flood are not taken into account.

4.6.2.3 Adaptation to flood crisis

Current structural flood protection measures for farmed shrimp are based on water levels and depths, while non-structural flood control measure emphasize on the management. Nowadays, there are two measures considered as the flood structural protection measures; dike height increase and netting around the pond. Meanwhile, two non-structural flood protection measures; early harvesting and shifting crop calendar, were observed. Another non-flood protection measure suggested by Thai shrimp newspaper (October 2004) to prevent flood caused by rainwater is to reduce feeding the shrimp during the period of big raining. Once the rainwater seems to be overflown the shrimp pond, throwing the large amount of feed into the center of the pond is recommended because shrimp swim against the current in order to eat feed at the bottom of the pond. Then, shrimp will not be flooded when flood waters overflown pond banks.

Most of shrimp farmers in Thailand don’t have secondary occupation apart from shrimp farming. Even though opting for relocation which is the adaptation option suggested by Ahmed (2006) may necessitate for long term planning, but it may not applicable for majority of Thai shrimp farmers who hold the right to use the land.

Moreover, relocation might not be socially accepted and need to be done through consultations among those involved. The shrimp farmers that would have to accept such relocation in their areas should be compensated for lost opportunities. As government has been pushing for an agricultural zoning program to develop Thailand's full-cycle agricultural system and help solve farmers' problems in the long run, the relocation or switching from shrimp farming to others may be under the governmental plan. Table 4.19 highlights a few adaptation measures resulting from the field survey at Chachoengsao province and research literatures.

Table 4.19 Adaptation measures and requirements for shrimp farming under flood risk.

Adaptation measures	Requirements	Comments
Bear loss (no adaptation) - Loss of production - Loss of assets		Hypothetical, highly unlikely to take place
Share losses - Crop insurance - Cooperative management - Governmental subsidies	Additional investment in terms of premium. Agreement for sharing the output. State allocation for offering subsidies. Adequate legal and institutional framework	Political motivation is required.
Modify the threats - Preparedness (early warning of flood) - Awareness and training - Investment for structural measures	- Research and extension - Extension, media campaign - Investment (anticipatory) - Crop calendar adjustment - Opting for less susceptible crops - Large investment - Political motivation - Long-term planning	Shrimp farmers are already practicing it, based on experience, behavior and knowledge. Manifold opportunities are plausible, barrier removal and implementation could be less costly. High priority option
Prevent adverse effects using structural measures (increase the dike height and netting around the pond)	- Large investment - Political motivation - Long-term planning	Investment intensive option. Financial constraints might hinder implementation processes

Prevent adverse effect using non-structural measure (abandon crop for particular period of time)	- Innovation through research and investment - Mean of survival, skills for alternative employment	Unless alternative employment opportunities are created, it is not likely to be accepted socially
Relocate to less vulnerable places	Free cultivable land	Heavily constrained due to unavailability of fallow farmland

Source: Modified from Ahmad (2000).

4.6.2.4 Limitation of shrimp farming adaptation

It is obviously that the existing institution used to combat with floods events had inherent inefficiencies, lack of foresight in planning for the future, poor condition and planning among relevant institutions, poor information assimilation capacity of shrimp farmers, and lack of investment in adopting flood structural measures. As a consequence, those often proved to be ineffective. The relevant local governments may not be utilized properly by central government due to the lack of resource for provision and contribution of the knowledge on the adaptation options. This made it difficult to implement in the development at the small-scale farm level. All these are possible barrier to successful adaptation, which might have direct implication for shrimp farming production in the future.

People’s lack of understanding on how to prevent the adverse damage by flood might also be considered as a possible barrier even though they are aware on flood damage. Capacity building might be a prerequisite to enhance people’s understanding. Poverty or debts over income are proved as another potential barrier. Many small scale shrimp farmers would not be able to take advantage of adaptation measures due to acute poverty. Therefore, financial investment would be appearing a major issue, especially among poor and small-scale shrimp farmers. Requirement for cash investment soon after a major flood event limit cultivation of cash for next crop. Lack of adequate credit facilities from both governmental and private banks for shrimp farmers is reported as major constraint of coping to floods. Recovery the pond after flooding is also revealed as opportunities cost as three months at least or equal to time used for one crop is required.

Weak institutional coordination especially among large number of local institutions dealing with shrimp farming and support facilities, might also be identified as a limitation. Strengthening of the extension service was found to be useful as an institutional adaptation towards safeguarding future shrimp farming activities. Table 4.20 summarizes the limitation and recommended solution to increase adaptation of shrimp farmers.

Table 4.20 Limitation for adaptation and suggested solutions.

Limitation	**How to solve**
Lack of foresight in planning for the future	- Capacity building might be a prerequisite to enhance people's understanding - Strengthening of the extension service among institutions
Poor condition and planning among relevant institutions	- Strengthening of the extension service among institutions
Poor information assimilation capacity of shrimp farmers	- Capacity building might be a prerequisite to enhance people's understanding
Lack of investment in adopting flood structural measures	- Financial assistance through loan or increasing credit ability
Local governments may not be utilized properly by central government due to the lack of resource for provision and contribution of the knowledge on the adaptation options	- Strengthening of the extension service for an institutional adaptation towards safeguarding future shrimp farming activities

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The aims from research questions of this thesis is how model for assessing vulnerable area of shrimp farms to flood can be best used to identify most risk areas to flood when flood seems to happen on regular basis as well as most effectiveness adaptations to reduce shrimp farmer’s vulnerability to floods. The thesis question is needed to identify relation to both the current climate conditions and future climate change scenario based on the results of climate projection over the study area carried out by Chula Uniresearch (2011). To make a complete set of current vulnerability assessment, social vulnerability was carried out and used to aggregate with physical vulnerability. Current adaptation practices identified during the site survey was also used as the baseline practice to investigate their effectiveness and cost-benefits. The current adaptations are primary reactive actions used to combat with flood events. These practices were also used to assess which adaptation would be most important in reducing shrimp farmer’s vulnerability to floods in the future. As some practices are required for the investment, the economic analysis of each adaptation measure was investigated. Prior doing that, flood risk map integrated with the total vulnerability map was produced based on the likelihood of flood as possible hazards. Then, damage cost and cost-benefit of each flood measure could be identified. Under the flood risk map, flooding will occur more frequently resulting in high impacts to shrimp farmer. Even though the inundation height is not evaluated, the entire shrimp in the pond can be washed away by the floods. This loss from flooding will also change the effectiveness of some of proactive adaptations in minimizing future vulnerability levels. Based on above provided results, this chapter discusses the implication for the shrimp farmers and broader policy in planning context. It concludes by recommending the most significant results and strategies available to those stakeholder for reducing vulnerability where flood control measure has become a regular work.

5.1 Predicting vulnerability of shrimp farm areas to floods

Current approaches to vulnerability assessment are focused on comparing the relative level of each vulnerability indicators in the study area of Chochoengsao province. Even though the current areas of vulnerability are highlighted, this approach ~~is~~ still lacks a capacity to predict the effectiveness of potential adaptation in reducing vulnerability. Since vulnerability assessment is useful tool to encompass all scales from the individual to geographical regions, the influence of public policy in both assessing vulnerable areas of shrimp farms to floods and suggesting appropriate actions to reduce the level of vulnerability in the future.

Current vulnerability assessment is preliminary step to identify the current situation of the shrimp farms in the study area to flood events. The combination of GIS and multicriteria evaluations has opened up new opportunities to overcome the challenges in assessing flood-vulnerable areas and implementing sustainable shrimp farming. GIS tools with a wide range of functions are now available for multiple purposes. In this study, flood vulnerability was assessed to identify the current flood-vulnerable shrimp farm areas in Chachoengsao Province, Thailand. Typical geo-environmental parameters including the slope, drainage density, soil texture, land use, and basin size were key components in the development of the vulnerability map of shrimp farms. The results revealed that shrimp farms in Chachoengsao are highly to very highly vulnerable to floods, although the assessment is only based on geographical data. Importantly, shrimp farms become more vulnerable to floods when the 10-day cumulative rainfall is greater than 300 mm.

Due to the high vulnerability of the geo-environmental conditions of the Bangpakong River Basin, the majority of shrimp farms are extremely vulnerable to floods. The shrimp farmers are more vulnerable when it is not possible to alter physical conditions including the slope, drainage density, soil texture, land use, and basin size in the future. The vulnerability of shrimp farmers increases when physical conditions are diagnosed together with social vulnerability covering three main factors: exposure, susceptibility and resilience vulnerability. Social vulnerability was assessed using twenty social indicators suggested by Unesco-IHE Institute for Water Education. Its results showed the same output as physical vulnerability assessment. Most of shrimp farmers from five out of the six districts (Ban Pho, Bang Khla, Khlong Khuenan, Muang and Ratchasan) were still classified in the high and very high social vulnerability. The Bang Khla and Ban Pho districts where can find the greatest number of shrimp farming area are considered to be the most socially vulnerable districts in Chachoengsao province.

To generate the total current vulnerability map based on integrating both physical and social vulnerability, two different sets of accumulated rainfall over 10 days between 250-300 mm and exceeding 300 mm were used to project the total vulnerability map, as these amounts of rainfall were recognized as the thresholds for flash floods in the study area. Results from interpretation of total current vulnerability map reveal that the vulnerability level of shrimp farms to flood is not significantly different. Shrimp farms in five districts are becoming more vulnerable to flood if there is no improvement of the socio-economic characteristics of shrimp farmers. Improving capacity and building resilience were proved as only one way to reduce the vulnerability level when relocation to the less vulnerable area is not possible. To make a better current vulnerability map; however, rainfall data from more than one rain gauges adjacent to Chachoengsao province should be used for further assessment.

The assessment of vulnerability should also be focused on variables to make the future flood worsen when comparing to the current vulnerability results. To develop a predictive approach to vulnerability assessment, results of climate projection over the study area carried out by Chula Uniresearch (2011) were adopted for future vulnerability assessment. Simulation of the future assessment was used by making change on rainfall pattern due to climate change to represent possible future conditions. However, the number of rainy days and the amount of rain over the next 30 years were projected by Chula Uniresearch to not differ from the current climate variables even though intensities of rainfall extreme events are projected to increase over time. As a result, a predictive assessment of vulnerable area to flood is therefore not differing from current vulnerability situation.

5.2 Possible adaptation practices

In this study, the indicators that can be influenced the adaptive capacity to reduce the social vulnerability of shrimp farmers were identified and assessed the ability to reduce the level of vulnerability. Prediction of the likely effectiveness of adaptations was made by both assessing current adaptations and modeling the likely effects when modify the social system or increase social ability. Comparing the relative effectiveness of different types of adaptive capacity indicators allows prioritization in responding the future floods.

The assessment of the effectiveness of adaptations on flood vulnerability reduction in future was done in predictive way. Five adaptive capacity indicators: education level, wealth or saving status, secondary occupations, farm experience and farm size, were subjected to comparisons of which indicators affect flood vulnerability and adaptation. Saving status and secondary occupations are the main influential factors impacting not only the adaptive capacity but also the vulnerability reduction. However, there was no statistically significant relationship between five of the adaptive capacity indicators and the choice of adaptation options to mitigate floods. The significance of the influence on implementing adaptation options very much depends on lessons learned from past flood experience.

Promoting income of shrimp farmers will reasonably increase saving. Better financial capacity can be made better saving. However, poverty reduction should be taken into account as it can be treated as one of factors in increasing vulnerability. Consequently, increased saving and policy for poverty alleviation will provide better readiness of shrimp farmer in responding to coming floods. Even though results of the modeling indicate that creating financial sources will increase shrimp farmer’s saving and ability to purchase, but it may not effectively decrease vulnerability level. Moreover, the knowledge for improving the effectiveness of both structural and non-structural measures to reduce the damage by floods should be encouraged in parallel. This is because increasing saving does not always increase the capacity of shrimp farmer to respond to floods. The extra budget for improving structural measures is likely to be spent consumptively until their saving leaving no remain in supporting for recovery. Therefore, creating secondary occupation for alternative income for shrimp farmer community should be accompanied by other mechanisms such as insurance mechanisms and OTOP project.

Based on the current vulnerability assessment, adaptation practices undertaken to reduce the impacts of flood were investigated. The majority of shrimp farms are already located in flood-prone areas. Therefore, all shrimp farmers have managed to implement practices to cope with the effects of flooding because they experienced the 2011 flood. These adaptation practices to reduce flood impacts include placing a net around the pond to prevent the escape of shrimp (57.2%), increasing the height of the dike around the shrimp pond (66.9%) and harvesting prior to flooding (31.0%). However, these practices did not completely eliminate the effects of floods. Especially flooding will be more frequent and damaging to the shrimp farming industry in Thailand in the future. On the other hand, flood events and adaptation measures could appear to be regular activities, especially on shrimp farms located in areas that are highly and very highly vulnerable to floods.

Minimizing damage from flooding in the future is a challenge due to the adaptation abilities of the stakeholders. Structural techniques for flood mitigation are considered to be the best choice in such a situation. However, the selected structural techniques applied by even large-scale shrimp farmers may not be sufficient to completely mitigate the damage caused by flood events, due to an inappropriate design for construction and prevention. Improvement of these structural measures is required for further investment. Financial constraints become the main obstacle to improving the adaptive capacity of small-scale shrimp farmers to implement structural flood control measures. Small-scale shrimp famers are more vulnerable because the majority of small shrimp famers are located in high vulnerability areas. Shrimp farmers may be unable to adapt rapidly by implementing structural mitigation techniques. Non-structural techniques associated with management practices, such as early harvesting prior to the occurrence of floods and changing the calendar for shrimp culture, should be promoted as alternatives. The accuracy of the local governmental offices' notifications of the rainfall quantity before imminent flooding is essential for non-structural techniques. Without further investments in adaptation practices, planned management, particularly harvesting before flooding, could be a good approach for particular small-scale shrimp farmers to manage flood problems/concerns. In addition, decreasing the exposure and sensitivity of small-scale shrimp farmers should be addressed through financial support mechanisms by the responsible agencies.

5.3 Economic terms of each measure for reducing vulnerability

Based on the flood risk map approximately 43.63% and 30.63% of total shrimp farm areas in Chachoengsao province are in extremely high risk and high risk to flood categories, respectively. These shrimp farms in the province are expected to be flooded with a 0.5 annual flood occurrence when accumulated rainfall for 10 days is greater than 250 mm. An estimated maximum annual damage costs for shrimp ponds for each rai (0.16 ha) is approximately 9,375 USD/event. This annual damage cost can become benefits if the damage caused by floods can be avoided. The damage costs from flood and/or opportunity costs of forgoing the current crop to invest for the next crop was found to be higher than the cost for investment of the structural flood control measures (for both increasing the height of dike and/or netting around the shrimp ponds). The opportunity costs are ten times and seventy-five times higher than costs for construction of the dike and netting around the pond, respectively. Sensitivity analysis based on two scenarios was performed in this study including: 1) not all shrimp farmer can invest in flood structural control measures and 2) flood structural measures may be ineffective under massive flood condition. Benefit or avoided damage cost from sensitivity analysis is reduced from seventy-five times to thirty-six times instead.

Costs of structural flood control measures are found to be much lower than the opportunity costs or potential damage costs from loss of income from forgoing the current crop. Investments in structural measures would yield avoided damage costs more than other flood adaptation measures. Even though structural flood control measures were proved to be economically viable options, but non-structural flood control would be an attractive alternative measure for shrimp farmers who lack sufficient financial means.

The study's survey showed that shrimp farmers decided to take the risk of flooding either with or without adaptation measures. It is; therefore, recommended that the farmers should plan to invest in construction of flood structural measures. Central and local governments can help improve the adaptation capacity of shrimp farmers by provide soft loans, educate local shrimp farmers who are in risk areas, and develop an effective flood advisory program. The effectiveness of each structural measure is; however, subjected to the inundation depth and velocities of floodwater. Impacts from these factors should be further analyzed in the future to further advance our understanding in effective adaptation planning.

Non-structural measures are still good alternative not only for shrimp farmers who lack the saving but also well-being farmers when the money is likely to be spent consumptively until their saving leaving no remain. However, shrimp farmers must accept to loss their income from avoided damage costs or income from raw shrimp harvesting. This may be a good time to make positive change on creating alternative income for shrimp farmers when prices for shrimp raw material in Thailand have dropped sharply. Moreover, most of shrimp farms have decided to stop cultivating the shrimp due to challenges from the EMS crisis in Thailand; small scale shrimp farmers who are in high risk area from any threats should be created alternative from other secondary occupation rather than in promoting to culture shrimp.

5.4 Policy and planning recommendation

There are two main measures to respond the incoming floods: structural flood control measures and non-structural flood control measures. However, each measure is required several things to make this implementation more effectiveness. Based on key results presented above, I would summarize recommendations for policy-making following:

1) The use of decision support tools particularly from modeling used to assess the current and future vulnerability scenario should be used to cooperate among international and national policy agencies for developing strategies for flood risk management

2) Government involvement is still required in enhancing the resilience used to reduce vulnerability level. Increasing adaptive capacity from increasing saving and creating alternative income are the main challenge to reduce the social vulnerability of shrimp farmers. Since shrimp farmer live below the poverty line, creating alternative economic sources may increase shrimp farmer's capacity to respond in coming floods. However, shrimp farmer may not be able to increase their capacity to access the financial sources. Supporting from government in applying other proactive approaches with external parties should be initiated such as flood insurance and OTOP
3) Providing knowledge of each structural flood control measure to make it more effectiveness is still important. Nowadays, no one know how to make structural measure adequately to prevent coming floods. However, further assessment on inundation depth should be studied.
4) The important impact of uncertainly in rainfall predictions should be one of the main focuses for future study especially intensify the monsoonal rainfall
5) With some adjustment, this assessment processes can be applied to other shrimp farm areas in other 24 provinces.
6) Prevention or mitigation the threats posed by flooding or even transform them into benefits by judicious management of water resource should be immediately initiated.

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APPENDIX A

QUESTIONNAIRE

แบบสอบถามเลขที่............................
ได้สอบถามวันที่.................................
สอบถามโดย......................................

แบบสอบถาม

แบบสอบถามชุดนี้ได้จัดทำเพื่อวัตถุประสงค์ในการสำรวจความคิดเห็นของเกษตรกรผู้เพาะเลี้ยงกุ้งทะเลในจังหวัดฉะเชิงเทรา เพื่อนำผลที่ได้ใช้ประกอบในการพิจารณาจัดทำดุษฎีวิทยานิพนธ์ในหัวข้อเรื่อง การประเมินความอ่อนไหวและการปรับตัวของฟาร์มเพาะเลี้ยงกุ้งทะเลต่อสถานการณ์น้ำท่วมฉับพลันภายใต้การเปลี่ยนแปลงสภาพภูมิอากาศ กรณีศึกษาที่ราบแม่น้ำบางปะกง ลุ่มน้ำบางปะกง จังหวัดฉะเชิงเทรา ของนายชัยพร สีขาว นิสิตปริญญาเอก สหสาขาวิชาด้านการจัดการสิ่งแวดล้อม จุฬาลงกรณ์มหาวิทยาลัย โดยมีวัตถุประสงค์ของการศึกษาวิจัยเพื่อ

1. ประเมินผลกระทบจากน้ำท่วมของฟาร์มเลี้ยงกุ้งภายใต้สถานการณ์ของการเปลี่ยนแปลงสภาพภูมิอากาศ และจัดทำแผนที่แสดงความเปราะบางต่อน้ำท่วมภายใต้แนวโน้มการเปลี่ยนแปลงสภาพภูมิอากาศในอนาคต
2. ประเมินระดับของความเสียหายจากน้ำท่วมและมูลค่าความเสียหายต่อผลผลิตกุ้งทะเล ซึ่งเกี่ยวข้องกับสภาพแวดล้อมและเศรษฐกิจในพื้นที่ศึกษา
3. เพื่อเสนอแนวทางในการปรับตัวและแนวทางในการป้องกันผลกระทบจากน้ำท่วมเพื่อให้มั่นใจได้ว่าการดำเนินการดังกล่าวจะทำให้เกิดความยั่งยืนต่อการเลี้ยงกุ้งในอนาคต

ส่วนที่ 1: ข้อมูลทั่วไปของการเพาะเลี้ยงกุ้งแบบบ่อดิน

กรุณากรอกข้อมูลของผู้ให้สัมภาษณ์หรือบุคคลที่สามารถติดต่อได้สำหรับข้อมูลที่ได้จากแบบสอบถามนี้:

ชื่อ-นามสกุล: ....

เพศ: ☐ ชาย ☐ หญิง อายุ: .... ปี

อาชีพเกี่ยวกับการเพาะเลี้ยงกุ้ง: ☐ เลี้ยงกุ้งเพียงอย่างเดียว ☐ ประกอบอาชีพอื่นด้วย; โปรดระบุ
....
..
โดยทำอาชีพเลี้ยงกุ้งมาแล้วเป็นระยะเวลา .... ปี

ประวัติการศึกษา: ☐ ไม่ได้ศึกษา ☐ ประถมศึกษา 4 (ป.4) ☐ ประถมศึกษา 6 (ป.6)
☐ ระดับมัธยมศึกษาตอนต้น ☐ ระดับมัธยมศึกษาตอนปลาย ☐ ระดับปริญญาตรี

☐ อื่นๆ ระบุ........
..

รายได้ต่อเดือน: .... บาท/เดือน คิดเป็นรายได้จากการเลี้ยงกุ้งอย่างเดียว .... บาท/เดือน

ความเป็นสมาชิกของชมรมผู้เลี้ยงกุ้ง: ☐ เป็น ระบุ ชื่อชมรม/สมาคม...
☐ ไม่เป็น

เป็นเกษตรกรผู้เลี้ยงกุ้งที่ขึ้นทะเบียนกับกรมประมงหรือไม่: ☐ เป็น ☐ ไม่เป็น

ที่อยู่:........
..
....
..

หมายเลขโทรศัพท์ที่สามารถติดต่อได้: ....
..

ตำแหน่งที่ตั้งฟาร์มทางพิกัดภูมิศาสตร์ (ผู้สัมภาษณ์เป็นคนดำเนินการ): N...................... P ....
..

ส่วนที่ 2: ข้อมูลทั่วไปของการเพาะเลี้ยงกุ้งแบบบ่อดิน

สายพันธุ์กุ้งที่เลี้ยงภายในฟาร์มหรือบ่อเดียวกัน: ☐ กุ้งดำอย่างเดียว ☐ กุ้งขาวอย่างเดียว
☐ ผสมระหว่างกุ้งขาวกับกุ้งก้ามกราม ☐ ผสมระหว่างกุ้งขาวกับปลา ระบุพันธุ์ปลา........
..
☐ อื่นๆ ระบุ........
..

ประเภทของบ่อเลี้ยงกุ้ง: ☐ บ่อดิน ☐ ร่องสวน

จำนวนบ่อ: บ่อเลี้ยง .... บ่อ ; บ่อพักน้ำ .... บ่อ; บ่อบำบัดน้ำ .... บ่อ; บ่อเก็บเลน .... บ่อ

จำนวนพื้นที่การเลี้ยงทั้งหมด: .... ไร่

ขนาดของบ่อเลี้ยงโดยเฉลี่ย: .... ไร่

โดยเฉลี่ยเลี้ยงกุ้งกี่รอบต่อปี: .... รอบ/ปี
มีช่วงระหว่างเดือนของแต่ละปีที่จะไม่ทำการเลี้ยงกุ้งเลยหรือไม่ ☐ มี (หากมีโปรดระบุต่อด้านล่าง)
☐ ไม่มี
หากมีจะไม่มีการเลี้ยงกุ้งในช่วงระหว่างเดือน .... ถึงเดือน ....ของแต่ละปี
เพราะสาเหตุใดโปรดระบุ ....

ปริมาณผลผลิตกุ้งต่อรอบโดยเฉลี่ย:.................... กิโลกรัม / บ่อ / รอบการเลี้ยง

ส่วนที่ 3: ข้อมูลทางด้านเศรษฐกิจ-สังคม

สถานะของเงินออมท่าน (ผู้เพาะเลี้ยงกุ้งทะเล): ☐ มี ☐ ไม่มี
หากมี โปรดระบุสถาบันการเงิน ....

ความมุ่งมั่นที่จะทำอาชีพเพาะเลี้ยงกุ้งในอีก 5 ปีข้างหน้า : ☐ มี ☐ ไม่มี

หากมีโปรดระบุเรียงลำดับถึงเหตุผลหลัก (ให้คะแนน 5) ไปหาเหตุผลที่น้อยที่สุด (ให้คะแนน 1) ตามรายละเอียดดังนี้

☐ เป็นอาชีพที่ความเสี่ยงน้อย ถึงแม้ว่าเคยถูกน้ำท่วมในบางปีแต่ก็อยู่ในระดับที่สามารถป้องกันและควบคุม ไม่ให้เกิดผลกระทบได้ หรือผลกระทบที่เกิดขึ้นอยู่ในระดับไม่มีเลย

☐ เป็นอาชีพหลักที่ทำมาเป็นเวลานานและไม่ทราบว่าจะประกอบอาชีพอะไรทดแทน

☐ คิดว่าอาชีพนี้เป็นอาชีพที่มั่นคงและให้ผลตอบแทนที่ดีสามารถเลี้ยงครอบครัวได้

☐ มีที่ดินเป็นของตนเองและไม่ต้องการโยกย้ายถิ่นฐานไปทำงานที่อื่น

☐ ไม่มีโอกาสที่จะประกอบอาชีพอย่างอื่น หรือไม่ทราบว่าจะประกอบอาชีพอะไรแทนอาชีพเลี้ยงกุ้งทะเล

ผลผลิตกุ้งที่จับได้จำหน่ายโดย: ☐ ด้วยตัวเอง ☐ ผ่านโบรกเกอร์ ☐ ผ่านแพปลา

เคยมีประสบการณ์ในการสูญเสียผลผลิตในระหว่างเลี้ยงหรือไม่ : ☐ มี ☐ ไม่มี

หากมีโปรดระบุสาเหตุ: ☐ โรคระบาด ☐ น้ำท่วม / ภัยธรรมชาติ ☐ ตายโดยไม่รู้สาเหตุ

☐ อื่นๆ ระบุ ....

ส่วนที่ 4: ผลกระทบจากน้ำท่วมในอดีต

1. โปรดระบุปีที่เกิดเหตุการณ์น้ำท่วมที่ฟาร์มเลี้ยงกุ้งของท่าน
    - a. ในกรณีตั้งแต่อดีตจนถึงปัจจุบัน..
    - b. ในรอบ 5 ปีที่ผ่านมา

☐ 2550 ในระหว่างเดือน .... ถึงเดือน .... หรือจากเหตุการณ์พายุ...........

☐ 2551 ในระหว่างเดือน .... ถึงเดือน .... หรือจากเหตุการณ์พายุ...........

☐ 2552 ในระหว่างเดือน .... ถึงเดือน .... หรือจากเหตุการณ์พายุ...........

☐ 2553 ในระหว่างเดือน .... ถึงเดือน .... หรือจากเหตุการณ์พายุ...........

☐ 2554 ในระหว่างเดือน .... ถึงเดือน .... หรือจากเหตุการณ์พายุ...........

☐ 2555 ในระหว่างเดือน .... ถึงเดือน .... หรือจากเหตุการณ์พายุ...........

2. ระดับของผลกระทบจากน้ำท่วมสูงสุดต่อฟาร์มกุ้งและชุมชนของคุณ (หากฟาร์มกุ้งของคุณเคยได้รับผลกระทบจากน้ำท่วม)

☐ ได้รับความเสียหายจากน้ำท่วมบางส่วน โปรดระบุ ระดับความเสียหาย .... % (หากพิจารณาได้)

☐ ได้รับผลกระทบจากน้ำท่วม 100% (หากตอบข้อนี้ โปรดตอบข้อ a และ b ตามรายละเอียดด้านล่าง)

- a. เกิดขึ้นในปี พ.ศ. ....

   b. คิดเป็นมูลค่าความเสียหาย .... บาท

3. มูลค่าความเสียหายที่เกิดจากการสูญเสียผลผลิตกุ้งจากเหตุการณ์น้ำท่วม 2 ครั้งล่าสุด (หากระบุได้ โปรดตอบข้อ 4 ต่อตามรายละเอียดด้านล่าง)
   a. ครั้งที่ 1 คิดเป็น .... % และเกิดขึ้นในปี พ.ศ. ....
   b. ครั้งที่ 2 คิดเป็น .... % และเกิดขึ้นในปี พ.ศ. ....

4. เงินชดเชยจากหน่วยงานรัฐที่ท่านได้รับ
   a. จากเหตุการณ์น้ำท่วมครั้งที่ 1 เท่ากับ .... บาท จาก............

   ซึ่งถือว่าเพียงพอหรือไม่ ☐ เพียงพอ ☐ ไม่เพียงพอ

   b. จากเหตุการณ์น้ำท่วมครั้งที่ 1 เท่ากับ .... บาท จาก............

   ซึ่งถือว่าเพียงพอหรือไม่ ☐ เพียงพอ ☐ ไม่เพียงพอ

5. โปรดระบุแหล่งที่มาหรือสาเหตุของน้ำท่วมที่ส่งผลกระทบต่อฟาร์มเลี้ยงกุ้งหรือชุมชนของคุณ

   ☐ จากการเออล้นของแม่น้ำบางปะกง

   ☐ จากการเออล้นของลำน้ำสาขาของแม่น้ำบางปะกง (โปรดระบุชื่อลำน้ำสาขา:

   ....

   ☐ จากน้ำไหลบ่าจากเขตอำเภอประจันตคามและอำเภอนาดี จังหวัดปราจีนบุรี

   ☐ จากฝนตกหนักที่ตกต่อเนื่องนานหลายวัน

   ☐ อื่นๆ โปรดระบุ: ....

6. ผลกระทบจากน้ำท่วมได้ส่งผลกระทบต่อสุขภาพและความปลอดภัยขอคุณในประเด็นไหนบ้าง

   ☐ ไม่มีผลต่อสุขภาพและความปลอดภัยเลย

   ☐ เจ็บป่วย บาดเจ็บ หรือได้รับผลกระทบด้านความปลอดภัยเล็กน้อย เช่น เกิดโรคน้ำกัดเท้า ท้องร่วง ขโมย

   ☐ เจ็บป่วย หรือบาดเจ็บหนัก เช่น ไฟดูด เกิดบาดทะยัก เป็นต้น

   ☐ อื่นๆ ระบุ ....

7. ผลกระทบจาก<u>น้ำท่วมครั้งที่รุนแรงที่สุด</u>มีผลต่อประเด็นด้านสิ่งแวดล้อมหรือไม่

   ☐ เล็กน้อยหรือไม่มีผลกระทบที่ทำลายสิ่งแวดล้อมเลย

   ☐ ทรัพยากรธรรมชาติถูกทำลายโดยน้ำท่วม และใช้ระยะเวลาฟื้นฟูอันสั้นน้อยกว่า 3 เดือน เช่น ต้นไม้ตายแต่ฟื้นตัวเองได้ใน 3 เดือน และการเกิดตะกอนดินตกค้างในบ่อ แต่ใช้เวลาจัดการสั้นกว่า 3 เดือน

☐ ทรัพยากรถูกทำลายโดยน้ำท่วม และใช้ระยะเวลาฟื้นฟูนานมากกว่า 3 เดือน เช่น ต้นไม้ตายถาวร เกิดตะกอนดินจนส่งผลกระทบต่อการเลี้ยงเป็นระยะเวลามากกว่า 1 รอบการเลี้ยง (3-4 เดือน) และเกิดการระบาดของหอยเชอร์รี่ในบ่อเลี้ยง

☐ อื่นๆ ระบุ ....

8. ผลกระทบจาก<u>น้ำท่วมครั้งที่รุนแรงที่สุดหรือครั้งล่าสุด</u>มีผลกระทบต่อด้านเศรษฐกิจต่อฟาร์มของท่านหรือไม่

☐ ไม่มีผลกระทบด้านเศรษฐกิจเลย

☐ มีผลกระทบด้านเศรษฐกิจสูงและ/หรือมีผลต่อต้นทุนทางอ้อมอื่นๆ เช่น ราคาอาหารกุ้งสูงขึ้น ต้นทุนในการเตรียมการเลี้ยง (ปรับปรุงบ่อ ขุดลอกเลน) สูงขึ้น

9. หากข้อ 8 ตอบมีผลกระทบด้านราคาอาหารกุ้งสูงขึ้น ให้ตอบคำถามต่อไปนี้

   a. ต้นทุนราคาอาหารกุ้งสูงขึ้น .... บาท/กระสอบ (ลูก)

   b. ต้องเปลี่ยนเกรดอาหารกุ้งให้ลดลงเพื่อลดค่าใช้จ่ายเรื่องราคาอาหาร

   ☐ ใช่ ☐ ไม่ใช่

10. ผลกระทบจากน้ำท่วมในครั้งที่รุนแรงที่สุด เมื่อเทียบกับเหตุการณ์น้ำท่วมครั้งที่ไม่รุนแรงมาก (เช่น เหตุการณ์น้ำท่วมที่มาเร็วและไปเร็ว เช่นฝนตกหนักติดต่อกันหลายวัน) มีอะไรที่เสียหายต่างกันบ้าง และระดับความเสียหายเป็นอย่างไร

เหตุการณ์ที่เกิดขึ้น	น้ำท่วมครั้งที่รุนแรงที่สุด ระบุปีที่เกิด พ.ศ.			น้ำท่วมที่เกิดประจำ หรือไม่รุนแรงมาก ระบุปีที่เกิด พ.ศ.		
	มาก	ปานกลาง	น้อย	มาก	ปานกลาง	น้อย
กุ้งตายหรือหลุดรอดจากน้ำท่วม						
มลพิษที่มากับน้ำและตกค้างในบ่อทำให้ผลผลิตกุ้งในรอบต่อไปลดลง						
โครงสร้างสำคัญเช่น บ่อ เครื่องตีน้ำ มอเตอร์ และโรงเก็บอาหารได้รับความเสียหายและยากต่อการซ่อมแซม						
คุณภาพของดินและความอุดมสมบูรณ์ของแร่ธาตุในดินลดลง						

เหตุการณ์ที่เกิดขึ้น	น้ำท่วมครั้งที่รุนแรงที่สุด ระบุปีที่เกิด พ.ศ.			น้ำท่วมที่เกิดประจำ หรือไม่รุนแรงมาก ระบุปีที่เกิด พ.ศ.		
	มาก	ปานกลาง	น้อย	มาก	ปานกลาง	น้อย
ผลกระทบจากตะกอนเหลนที่ตกค้างในบ่อภายหลังจากน้ำท่วม						
ระยะเวลาที่ใช้ในการฟื้นฟูปรับปรุงสภาพบ่อเลี้ยงก่อนปล่อยกุ้งรอบถัดไป						

ส่วนที่ 5: การเตรียมการ ป้องกัน และฟื้นฟูผลกระทบจากน้ำท่วมในอดีต
(หากข้อมูลในส่วนที่ 2 คือ ได้รับผลกระทบจากน้ำท่วม)

1. ท่านได้มีการเตรียมการเพื่อป้องกันและลดผลกระทบจากน้ำท่วมหรือไม่
   ☐ ไม่เคยมีการเตรียมการป้องกัน
   ☐ มีการเตรียมการป้องกัน (โปรดตอบคำถามข้อต่อไป)
2. หากท่านเคยมีการเตรียมการและป้องกันผลกระทบจากน้ำท่วมท่านได้ทำอะไรบ้างและสิ่งเหล่านั้นสัมฤทธิ์ผลหรือไม่ในเหตุการณ์น้ำท่วม 2 ครั้งล่าสุด

ท่านได้มีการดำเนินการป้องกันอย่างไรบ้าง (หากตอบทำให้ระบุความสามารถในการป้องกันน้ำท่วมในช่องถัดไป)	สามารถป้องกันและลดผลกระทบจากน้ำท่วมได้หรือไม่
☐ ทำ ☐ ไม่ทำ : การขึงอวน/ล้อมอวนรอบบ่อกุ้ง	☐ ได้ทั้งหมด ☐ ได้บางส่วน ☐ไม่ได้
☐ ทำ ☐ ไม่ทำ : การถมดินคันบ่อให้สูงขึ้นกว่าระดับน้ำ	☐ ได้ทั้งหมด ☐ ได้บางส่วน ☐ไม่ได้
☐ ทำ ☐ ไม่ทำ : การจับกุ้งจำหน่ายก่อนน้ำท่วม	☐ ได้ทั้งหมด ☐ ได้บางส่วน ☐ไม่ได้
อื่นๆ ระบุ	☐ ได้ทั้งหมด ☐ ได้บางส่วน ☐ไม่ได้

3. หากดำเนินการขึงอวน/ล้อมอวน เพื่อเตรียมการป้องกันน้ำท่วม โปรดตอบคำถามด้านล่าง

a. ค่าอวนที่ได้ซื้อมา .... บาทต่อการขึงรอบบ่อเลี้ยง 1 บ่อ

4. หากดำเนินกาถมคันบ่อให้สูงกว่าระดับน้ำท่วมเพื่อเตรียมการป้องกันน้ำท่วม โปรดตอบคำถามด้านล่าง

a. รถตักหรือรถขุดดินที่ใช้เป็นของตนเองหรือไม่ ☐ เป็น ☐ ไม่เป็น

b. หากไม่เป็น ค่าใช้จ่ายที่ต้องเสียต่อการเสริมคันบ่อเลี้ยง 1 บ่อเป็นเงินเฉลี่ย .... บาท ซึ่งถือว่าเป็นราคาปกติหรือไม่ ☐ เป็น ☐ ไม่เป็น

c. ความยุ่งยากในการติดต่อรถขุดดิน ☐ ไม่มี

☐ มี เพราะระบุ ....

5. เพื่อนเกษตรกรหรือสมาคมที่ท่านเป็นสมาชิกอยู่ได้มีการร่วมมือกันในการดำเนินการป้องกันและลดผลกระทบจากน้ำท่วมหรือไม่

☐ มี โปรดระบุกิจกรรมที่ทำร่วมกัน

1. ....

2. ....

3. ....

☐ ไม่มี

6. ท่านได้รับความช่วยเหลือจากภาครัฐหรือหน่วยงานที่เกี่ยวข้องเกี่ยวกับแนวทางในการป้องกันและลดผลกระทบจากน้ำท่วมหรือไม่

a. จากเหตุการณ์น้ำท่วมครั้งล่าสุด

☐ ได้รับ โปรดระบุประเภทการให้ความช่วยเหลือ

1. ....

2. ....

3. ....

☐ ไม่ได้รับ

b. จากเหตุการณ์น้ำท่วมก่อนครั้งล่าสุด

☐ ได้รับ โปรดระบุประเภทการให้ความช่วยเหลือ

1. ....

2. ....

3. ....

☐ ไม่ได้รับ

7. ท่านได้รับเงินสนับสนุนหรืองบประมาณในการจัดเตรียมป้องกันผลกระทบจากน้ำท่วมจากไหน

☐ จากแหล่งทุนอื่นๆ โปรดระบุ ....

☐ จากงบประมาณของตัวเอง

8. จากเหตุการณ์น้ำท่วมครั้งล่าสุด ท่านได้รับการแจ้งเตือนล่วงหน้าถึงข่าวน้ำท่วมที่จะส่งผลกระทบต่อฟาร์มกุ้งของท่านหรือไม่อย่างไร

☐ ได้รับ (โปรดระบุแหล่ง ซึ่งสามารถตอบได้มากกว่า 1 แหล่ง ตามรายละเอียดด้านล่าง)

จาก ☐ หนังสือราชาการของหน่วยงานรัฐ ☐ หนังสือพิมพ์/ข่าว
☐ เพื่อนเกษตรกร/สมาคม ☐ สังเกตการณ์ในพื้นที่จริงด้วยตนเอง

☐ ไม่ได้รับทราบข่าวจากทางใดๆ เลย

9. หลังจากเหตุการณ์น้ำท่วม ท่านได้มีการฟื้นฟูฟาร์มเลี้ยงกุ้งของท่านหรือไม่ที่นอกเหนือจากที่ต้องทำเป็นปกติจากการเลี้ยงกุ้งในกรณีที่ไม่เคยถูกน้ำท่วม

☐ มี
☐ ไม่มีอะไรเป็นพิเศษ

10. หากข้อ 9 ตอบมี สามารถตอบว่าได้ทำอะไรบ้างเพื่อเป็นการฟื้นฟูที่นอกเหนือจากกรณีที่ฟาร์มกุ้งของท่านไม่เคยถูกน้ำท่วมมาก่อน (ตอบได้มากกว่า 1 ข้อ)

☐ จับหอยเชอร์รี่
☐ ใส่ปูนขาว ปูนมาร์ล ปูนโดโลไมท์ และอื่นๆ มากกว่าปกติ
☐ ตากแดดนานมากกว่าปกติ
☐ ใส่จุลินทรีย์เพื่อบำบัดสิ่งปฏิกูล
☐ ใส่ปุ๋ยต่างๆ มากกว่าปกติ
☐ ซ่อมแซมคันบ่อเลี้ยง

11. จากคำตอบในข้อ 10 ต้นทุนในการเตรียมบ่อสูงขึ้นเฉลี่ย .... บาท/การเตรียมการในรอบการเลี้ยงต่อไป โดยเป็นค่าใช้จ่ายที่เพิ่มขึ้นจาก

☐ ค่ารถตักเลน .... บาท
☐ ค่าปูนต่างๆ .... บาท
☐ ค่าจุลินทรีย์ .... บาท
☐ ค่าปุ๋ย .... บาท
☐ ค่าจ้างจับหอยเชอร์รี่ .... บาท
☐ อื่นๆ ระบุ .... จำนวนเงิน .... บาท

12. งบประมาณที่ใช้ในการฟื้นฟูฟาร์มเลี้ยงกุ้งมาจากไหน

☐ จากแหล่งทุนอื่นๆ โปรดระบุ ....
☐ จากเงินช่วยเหลือที่ได้รับจากภาครัฐ
☐ จากงบประมาณของตัวเอง

13. ระยะเวลาที่ใช้ในการฟื้นฟูบ่อเลี้ยงกุ้งของท่านหลังจากเหตุการณ์น้ำท่วมครั้งล่าสุด .... เดือน

ส่วนที่ 6: การประเมินผลกระทบน้ำท่วมในอนาคต

1. คุณคิดว่าสถานที่การเลี้ยงกุ้งที่มีความเสี่ยงต่อการถูกน้ำท่วมมากที่สุดคือที่ไหนและมีระดับความเสี่ยงเป็นอย่างไรจากประสบการณ์และความคิดของท่าน

	เสี่ยงมาก	ค่อนข้างเสี่ยง	เสี่ยงน้อย	ไม่เสี่ยงเลย
พื้นที่ที่อยู่ใกล้แม่น้ำบางปะกงและลำน้ำสาขาต่างๆ				
พื้นที่ที่อยู่ใกล้เขาใหญ่หรืออำเภอประจันตคาม อำเภอนาดี จังหวัดปราจีนบุรี				
พื้นที่ที่อยู่ทางด้านฝั่งตะวันออกของแม่น้ำบางปะกงและอยู่ใกล้กรุงเทพฯ				
พื้นที่ที่อยู่ใกล้ถนน 304				
พื้นที่อื่นๆ โปรดระบุ				

หมายเหตุ: 1. เสี่ยงมาก คือ เกิดน้ำท่วมได้ง่ายแม้เจอฝนตกหนักในระยะเวลาไม่กี่วัน และใช้เวลาฟื้นฟูบ่อเลี้ยงนานกว่า 3 เดือน

1. ค่อนข้างเสี่ยง คือ เกิดน้ำท่วมได้ง่ายก็ต่อเมื่อมีข่าวฝนตกหนักจากพายุเข้า น้ำทะเลหนุนสูง และจากการบริหารจัดการน้ำที่ไม่ดีของภาครัฐ ใช้เวลาฟื้นฟู 1-3 เดือน
2. เสี่ยงน้อย คือ เกิดน้ำท่วมได้หากเกิดเหตุสุดวิสัย แต่น้ำท่วมอยู่ไม่นาน และมีระยะเวลาในการฟื้นฟูได้สั้นน้อยกว่า 1 เดือน
3. ไม่เสี่ยงเลย คือ ไม่ว่าจะเกิดเหตุการณ์ใดๆ เช่น พายุเข้า หรือการบริหารจัดการน้ำที่ผิดพลาดก็จะไม่เกิดน้ำท่วมเลย

คำตอบข้างต้นได้ให้ข้อมูลบนพื้นฐานของ ☐ ประสบการณ์โดยตรงของผู้ให้ข้อมูล ☐ ข้อมูลที่ได้รับจากรัฐ สถาบันการศึกษา หรือสมาคมต่างๆ อื่นๆ ระบุ.......

2. การเปลี่ยนแปลงที่ส่งผลกระทบต่อปริมาณน้ำแบบไหนที่คุณคิดว่าเป็นการเปลี่ยนแปลงที่เห็นได้อย่างชัดเจนเมื่อเทียบกับ 5 ปีที่แล้ว โปรดระบุระดับของการเปลี่ยนแปลงดังกล่าวจากระดับมาก

ที่สุด มาก ปานกลาง ค่อนข้างน้อย และน้อย ตามที่คุณประสบมา พร้อมระบุช่วงเวลา (เดือน) ในแต่ละปีที่มักจะเกิดการเปลี่ยนแปลงเหล่านั้นเกิดขึ้น

เหตุการณ์การเปลี่ยนแปลง	ระดับของการเปลี่ยนแปลงในรอบ **5** ปีที่ผ่านมา
ฝนตกหนักขึ้นและตกเป็นเวลานานหลายวันมากขึ้น	☐ มากที่สุด ☐ มาก ☐ ปานกลาง ☐ ค่อนข้างน้อย ☐ น้อยที่สุด ระบุช่วงเดือนที่มีการเปลี่ยนแปลง........................-....... --
การเพิ่มขึ้นของความถี่ของการเกิดน้ำท่วม	☐ มากที่สุด ☐ มาก ☐ ปานกลาง ☐ ค่อนข้างน้อย ☐ น้อยที่สุด ระบุช่วงเดือนที่มีการเปลี่ยนแปลง........................-....... --
การเพิ่มขึ้นของความถี่ในการเกิดภาวะแห้งแล้ง	☐ มากที่สุด ☐ มาก ☐ ปานกลาง ☐ ค่อนข้างน้อย ☐ น้อยที่สุด ระบุช่วงเดือนที่มีการเปลี่ยนแปลง........................-....... --
อากาศหนาวและหนาวติดต่อกันหลายวันมากขึ้น	☐ มากที่สุด ☐ มาก ☐ ปานกลาง ☐ ค่อนข้างน้อย ☐ น้อยที่สุด ระบุช่วงเดือนที่มีการเปลี่ยนแปลง........................-....... --
อื่นๆ โปรดระบุ....... --	☐ มากที่สุด ☐ มาก ☐ ปานกลาง ☐ ค่อนข้างน้อย ☐ น้อยที่สุด ระบุช่วงเดือนที่มีการเปลี่ยนแปลง........................-....... --

3.จากการเปลี่ยนแปลงสภาพภูมิอากาศในข้อ 2 โปรดระบุระดับของผลกระทบจากการเปลี่ยนแปลงต่างๆ ที่มีผลต่อการเพาะเลี้ยงกุ้งทะเล โดยการทำเครื่องหมาย ✓ ลงในช่องที่คุณคิดว่ามีหรือไม่มีผลกระทบ พร้อมทั้งระบุผลกระทบจากการเปลี่ยนแปลงต่างๆ นั้นต่อการเลี้ยงกุ้งของท่าน

	มีผลกระทบทางบวก	มีผลกระทบทางลบ	ไม่มีผลกระทบหรือไม่ส่งผลต่อการ	หากมีผลกระทบทางลบ โปรดระบุผลกระทบที่เกิดขึ้นต่อการเลี้ยงกุ้งของท่าน
ฝนตกหนักขึ้นและตกเป็นเวลานานหลายวันมากขึ้น				---------
ปริมาณน้ำจากคลองธรรมชาติที่จะดึงมาใช้ในการเลี้ยงลดลงหรือไม่เพียงพอ				---------
การแปรปรวนของความถี่และปริมาณน้ำฝนเพิ่มมากขึ้น				--------
คุณภาพน้ำผิวดินมีคุณภาพลดลง				--------
ความเสี่ยงน้ำท่วมเพิ่มมากขึ้น				--------
ความเสี่ยงภัยแห้งแล้วเพิ่มมากขึ้น				--------
น้ำเค็มจากแม่น้ำบางปะกงหนุนสูงขึ้น				---------
อื่นๆ โปรดระบุ				--------

4. โปรดทำเครื่องหมาย ✓ ผลกระทบหลังน้ำท่วมจะก่อให้เกิดการเปลี่ยนแปลงหรือปัญหาต่อการเพาะเลี้ยงกุ้งในประเด็นอะไรบ้างที่ไม่ใช่ทางด้านการเงินและเศรษฐกิจและระดับของปัญหานั้นเป็นอย่างไร

	มากที่สุด	ค่อนข้างมา	ปานกลาง	ค่อนข้าง	น้อยที่สุด	หากตอบมาก หรือ ค่อนข้างมาก โปรดระบุวิธีการแก้ไข
ใช้ระยะเวลาในการฟื้นฟูมากและเสียโอกาสในการลงทุนในคร็อปถัดไป						
ใช้ระยะเวลาในการปรับสภาพบ่อนานกว่าปกติ						

	มากที่สุด	ค่อนข้างมา	ปานกลาง	ค่อนข้าง	น้อยที่สุด	หากตอบมาก หรือ ค่อนข้างมาก โปรดระบุวิธีการแก้ไข
ใช้เวลาในการเตรียมน้ำนานกว่าปกติ						
ปฏิทินการเพาะเลี้ยงกุ้งจากเดิมเปลี่ยนแปลงในปีต่อไป						
จำนวนรอบการเลี้ยงกุ้งในปีถัดไปลดลง						
กุ้งมีผลผลิตลดลงเมื่อเทียบกับครั้งก่อนน้ำท่วม แม้ว่าจะมีลักษณะการเลี้ยงเหมือนกัน						

ส่วนที่ 7: มาตรการการปรับตัวในอนาคตอีก 5 ปีข้างหน้า

1. โปรดทำเครื่องหมาย ✓ มาตรการการปรับตัวที่ท่านคิดว่าจะสามารถดำเนินการเพื่อป้องกันเหตุการณ์น้ำท่วมต่อฟาร์มเลี้ยงกุ้งของท่านและประสิทธิภาพในการป้องกันผลกระทบจากน้ำท่วมจากมาตรการนั้นที่ท่านคิด ทั้งนี้ ท่านสามารถเพิ่มเติมมาตรการได้หากเป็นมาตรการที่นอกเหนือจากนี้

มาตรการการปรับตัว	แผนการที่จะดำเนินการ		ประสิทธิภาพในการปรับตัว	
	ได้กำหนดว่าจะทำแน่นอนภายใน **3** ปีข้างหน้า	ยังไม่ได้กำหนดว่าจะทำอย่างแน่นอน	มีประสิทธิภาพในการป้องกันน้ำท่วมสูง (100%)	จะสามารถช่วยป้องกันน้ำท่วมได้บางส่วน
การป้องกันด้านโครงสร้าง				
การเพิ่มขีดความสามารถต่อการป้องกันน้ำท่วมฟาร์ม เช่น การปรับปรุงระบบระบายน้ำภายในฟาร์ม				
การเพิ่มความสูงของคันบ่อเลี้ยงเพื่อป้องกันน้ำท่วม				
ในกรณีที่พื้นที่เลี้ยงกุ้งของคุณอยู่ในชุมชนหรือบริเวณที่ใช้ทรัพยากรต่างๆ รวมกัน คุณและชุมชนของคุณจะทำโครงสร้างที่สามารถป้องกันน้ำท่วมร่วมกัน				
แผนการปฏิบัติงานในการป้องกันน้ำท่วม หรือทางด้านเทคนิค				

มาตรการการปรับตัว	แผนการที่จะดำเนินการ		ประสิทธิภาพในการปรับตัว	
	ได้กำหนดว่าจะทำแน่นอนภายใน **3** ปีข้างหน้า	ยังไม่ได้กำหนดว่าจะทำอย่างแน่นอน	มีประสิทธิภาพในการป้องกันน้ำท่วมสูง (100%)	จะสามารถช่วยป้องกันน้ำท่วมได้บางส่วน
การจัดทำอวนหรือข่ายรอบหรือเหนือบ่อเพื่อป้องกันการหลุดรอดของกุ้ง				
จับกุ้งจำหน่ายทันทีเมื่อทราบว่าน้ำจะท่วม				
เปลี่ยนแปลงเลี้ยงสัตว์น้ำประเภทอื่นที่ทนต่อน้ำท่วมในช่วงที่จะเกิดน้ำท่วม				
ทางด้าน practice				
เปลี่ยนแปลงปฏิทินการเลี้ยงรายปีเพื่อหลีกเลี่ยงปัญหาน้ำท่วมที่จะเกิดขึ้นทุกปี				
ปรับปรุงแนวทางในการรับรู้ข้อมูลการคาดการณ์น้ำท่วมผ่านช่องทางต่างๆ เช่น ข่าวสาร สมาคม การสังเกตการณ์โดยตรง และข้อมูลอื่นๆ				
ทางด้านการเงิน				
หาการประกันความเสียหายจากน้ำท่วมจากธนาคาร หรือหน่วยงานต่างๆ				
หางบประมาณเพื่อการลงทุนในการป้องกันน้ำท่วมอย่างถาวร				
อื่นๆ ระบุ				

2. หากท่านมีแผนที่จะลงมือดำเนินการตามแผนที่คาดว่าจะทำในอีก 3 ปีข้างหน้า อะไรเป็นสาเหตุที่ทำให้ท่านตัดสินใจแบบนั้น

☐ ท่านประเมินด้วยตนเองแล้วพบว่าความถี่ของน้ำท่วมต่อฟาร์มกุ้งของท่านจะเกิดขึ้นบ่อยมากยิ่งขึ้น

☐ ท่านทราบข้อมูลการคาดการณ์เหตุการณ์น้ำท่วมล่วงหน้าจากภาครัฐหรืองานวิจัยต่างๆ ต่อพื้นที่การเลี้ยงของท่าน เช่น ข้อมูลพายุ ข้อมูลแบบ real-time

☐ สมาคมหรือหน่วยงานรัฐบาลแนะนำให้ท่านทำ

☐ ต้องการประกอบอาชีพเลี้ยงกุ้งต่อไป

☐ อื่นๆ โปรดระบุ.............

ส่วนที่ 8: ข้อมูลเพื่อการใช้ในการประกอบการตัดสินใจของท่าน

1. ท่านทราบหรือไม่ว่ามีหรือไม่มีข้อมูลหรือเครื่องมือต่างๆ เพื่อช่วยท่านในการตัดสินใจดำเนินการป้องกันผลกระทบจากน้ำท่วมได้อย่างถูกต้องมากยิ่งขึ้น โดยโปรดทำเครื่องหมาย ✓ ในช่องที่ท่านต้องการ

ข้อมูล/เครื่องมือที่ช่วยท่านในการดำเนินการป้องกันน้ำท่วม	ข้อมูลเหล่านี้ท่านทราบหรือไม่ว่ามีหรือไม่		หากไม่มีท่านต้องการข้อมูลเหล่านี้หรือไม่	
	มี	ไม่มี	ต้องการ	ไม่ต้องการ
ข้อมูลพื้นที่เลี้ยงกุ้งที่เสี่ยงและเปราะบางต่อการได้รับน้ำท่วม				
ขั้นตอนและแนวทางในการปรับตัวต่อเหตุการณ์น้ำท่วม				

2. อะไรเป็นสิ่งจำเป็นที่สุดที่ท่านต้องการนำไปใช้ในการปรับตัวเพื่อการป้องกันและลดผลกระทบจากน้ำท่วมต่อฟาร์มเลี้ยงกุ้งของท่าน ระหว่างการเงิน ข้อมูลการคาดการณ์น้ำท่วม และแนวทางในการปรับตัวเพื่อป้องกันและลดผลกระทบจากน้ำท่วม โดยระบุคะแนน 3 ในด้านที่ท่านต้องการมากที่สุด คะแนน 2 คือด้านที่ท่านต้องการเป็นอันดับสอง และคะแนน 1 ในด้านที่ท่านต้องการน้อยที่สุด

☐ งบประมาณทางการเงิน
☐ แนวทางในการปรับตัวเพื่อป้องกันและลดผลกระทบจากน้ำท่วม
☐ ข้อมูลการคาดการณ์น้ำท่วม

อื่นๆ ถ้ามี โปรดระบุ ....

-------ขอขอบคุณที่ท่านเป็นส่วนหนึ่งในการจัดทำการประเมินผลกระทบจากน้ำท่วมที่มีต่อการเลี้ยงกุ้ง--------

APPENDIX B
RESULTS FROM QUESTIONNAIRE SURVEYS

Table 1

General information of shrimp farmer

Description	Ban Pho		Bang Khla		Khlong Khuean		Muang		Ratchasan		Bang Nam Priao	
	No	%	No	%	No	%	No	%	No	%	No	%
Sampling size	50	100	26	100	22	100	5	100	3	100	3	100
1. General information												
1.1 Gender												
- Male	0	0	19	73	19	86	2	40	2	67	1	33
- Female	10	20	8	31	18	82	3	60	1	33	2	67
1.2 Average age of shrimp farmer	52		50		46		49		63		47	
1.3 Occupation (related to shrimp farming)												
- Only shrimp farming	4	8	19	73	10	45	3	60	2	67	2	67
- Shrimp farming and other occupation	5	10	7	27	12	55	2	40	1	33	1	33
1.4 Average years of experience in shrimp farming	52		15		46		20		12		19	
1.5 Average income from other occupations (per month)	52		20714		21667		9000		N/A		110000	

1.6	Average income from shrimp farming only (per month)	52		26981		54725		15000		5000		95083	
1.7	Education												
	- No education background	0	0	1	4	1	5	0	0	0	0	0	0
	- Primary school year 4	9	18	13	50	6	27	3	60	3	100	0	0
	- Primary school year 6	0	0	5	19	7	32	2	40	0	0	0	0
	- Secondary school	0	0	4	15	5	23	0	0	0	0	0	0
	- High school	0	0	3	12	4	18	0	0	0	0	2	67
	- Bachelor degree			0	0	0	0					1	33
	- Post graduate degree	0	0	0	0	0	0	0	0	0	0	0	0
1.8	Has you been registered with Department of Fisheries												
	- Yes	10	20	25	96	35	159	5	100	3	100	3	100
	- No	0	0	1	4	1	5	0	0	0	0	0	0
2.	**Information about shrimp production**												
2.1	Shrimp species used for rearing												
	- White shrimp ((Litopenaeus vannamei)	8	16	2	8	2	9	1	20	1	33	2	67
	- Black tiger shrimp (Penaeus monodon)		0		0		0	2	40	0	0	0	0
	- Mixed between white shrimp and prawn	38	76	22	85	20	91	2	40	2	67	1	33
	- Mixed between white shrimp and fish	4	8	2	8	0	0	0	0	0	0	0	0
2.2	Number of shrimp ponds	52		4		46		2		4		12	
2.3	Total area of shrimp farming (rai)	52		13		46		6		23		56	
2.4	Average pond size (rai)	52		3		46		3		4		3	

2.5	Average annual production (crop/yeare)	52		3		46		2		3		3	
2.6	Is there any period of time to stop rearing shrimp												
	- Yes	10	20	21	81	31	141	5	100	2	67	3	100
	- No	0	0	5	19	5	23	0	0	1	33	0	0
2.7	Average shrimp production per crop (kg/pond/crop)	52		542		46		430		1067		1217	
3.	**Socio-economic information of shrimp farmer**												
3.1	Do you have any saving?												
	- Yes	10	20	4	15	12	55	1	20	0	0	3	100
	- No	0	0	22	85	22	100	4	80	3	100	0	0
3.2	Do you still intend to do shrimp farm?												
	- Yes	10	20	21	81	19	86	5	100	3	100	2	67
	- No	0	0	5	19	3	14	0	0	0	0	1	33
3.3	What are main reasons to make you insist with shrimp farming career? Range score from 5 (highest) to 1 (lowest)												
	- Even though the shrimp pond has encountered with flood, but it is few risky and mitigation and preventive actions can be done to cope with flood	3		3		4		2		5		3	

easily. Then, the effect from flood is none.												
- Shrimp farming has been taken for long time ago and do not know any replacement career	5		4		2		4		4		3	
- It is stable career with good return revenue for family	3		3		2		3		3		3	
- Shrimp ponds are reared on own lands and do not want to migrate to work in different area	2		3		2		5		2		4	
- No opportunity to work with new career and do not know which career can be replaced for shrimp farming	2		3		3		1		1		2	
3.4 Harvested shrimp will be sold out by												
- Shrimp farmer itself	24	48	11	42	11	50	0	0	1	33	0	0
- Trader (broker)	11	22	0	0	0	0	0	0	0	0	0	0
- Fish market	15	30	15	58	11	50	5	100	2	67	3	100
3.5 Do you have an expereince to loss or damage the shrimp production during the cultivation?												
- Yes	50	100	26	100	22	100	5	100	3	100	3	100
- No	0	0	0	0	0	0	0	0	0	0	0	0
3.6 What are the reasons to make the damage?												
- Disease outbreak	50	100	20	77	22	100	5	100	3	100	2	67

- Flooding	50	100	11	42	22	100	3	60	3	100	3	100
- Death by unknown causes	34	68	7	27	12	55	5	100	3	100	1	33
4. Effects of recently flooding in last 6 years												
4.1 Which year in the last 5 years did you encounter with flooding?												
- Year 2008	0	0	0	0	0	0	0	0	0	0	0	0
- Year 2009	0	0	0	0	0	0	0	0	0	0	0	0
- Year 2010	0	0	0	0	0	0	0	0	0	0	0	0
- Year 2011	50	100	26	100	22	100	5	100	3	100	3	100
- Year 2012	47	94	25	96	21	95	3	60	3	100	3	100
4.2 Did the worst floods that you encountered in the last 5 years make any damages on your shrimp farm?												
- Partial damage on shrimp farm	5	10	3	12	2	9	0	0	0	0	1	33
- 100% damage on shrimp farm	45	90	21	81	20	91	5	100	3	100	2	67
- No damage occurred on shrimp farm	0	0	2	8	0	0	0	0	0	0	0	0
4.3 Which year was caused of the worst flood in the last 5 year?	2011		2011		2011		2011		2011		2011	
4.4 Average estimated damage value from the worst flood (Thai Baht)	98769		143333		122300		82500		100000		300000	

4.5	If you have experienced from flooding more that one in the last 5 years, which year did you still encounter with flooding?	2011, 2012		2011, 2012		2011, 2012		2012		2012		2012	
4.6	How many shrimp farmers have experienced on flooding for 2 times in the last 5 years?	47		23		21		3		3		3	
4.7	The effect from flood from that year answered in 4.5 made either partial damage or 100% damage												
	- Partial damage on shrimp farm	9	18	20	77	3	14	1	20	3	100	3	100
	- 100% damage on shrimp farm	41	82	3	12	19	86	2	40	0	0	0	0
4.8	Average flood duration (days) from worst flood												
4.9	Averaged relief fund provided by Department of Fisheries (Thai Baht)	9875		19776		18750		28000		23450		125000	
4.10	Based on your experience, what are causes and sources of flooding to your shrimp farm?												
	- From overflown the Bangpakong river banks	3	6	2	8	11	50	5	100	0	0	1	33
	- From overflown from tributary banks	37	74	0	0	9	41	1	20	0	0	1	33
	- Water runoff from Prachantakham and Nadee district of Prachinburi province	4	8	23	88	0	0	2	40	3	100	1	33
	- Heavy rainfall for several days	6	12	1	4	2	9	1	20	0	0	2	67

4.11	What are effects from flooding on your health and safety?												
	- No any effects on health and safety	37	74	7	27	8	36	5	100	1	33	1	33
	- Slightly affect on illness and safety i.e. athlete's foot, diarrhoea, burglary	13	26	19	73	14	64	0	0	2	67	1	33
	- Serious illness i.e. electric shock and tetanus		0	0	0		0	0	0	0	0	0	0
4.12	What are effects from the worst flood in the last 5 year on the environmental aspect?												
	- No any impacts on the environment	4	8	1	4	7	32	2	40	0	0	1	33
	- Local environment was damaged by flood i.e. tree and fruit tree were drown by flooding, but the recovery time was less than 3 months. Sediment and organic matter build up in the pond and take 3 months to remove it before new stocking	34	68	15	58	13	59	0	0	0	0	0	0
	- Local environment was dramatically damaged by flooding i.e. tree is dead permanently. Environment need more than 3 months for recovery. Sediment and organic matter buid up in the pond and need more than 3 months or shrimp farmer need to stop rearing for 1 crop (4 months) for removing the sediment. Massive golden apple snail outbreaks	12	24	10	38	2	9	3	60	3	100	2	67

4.13	Is there any effect of worst flood on your economic for shrimp culture?												
	- No any effect on shrimp culture economic	3	6	1	4	1	5	1	20	0	0	1	33
	- Economic of shrimp farm is affected by flooding i.e. shrimp feed prices keep increasing up, costs for preparness before next stocking were increased	47	94	25	96	21	95	4	80	3	100	2	67
4.14	If the answer in 4.13 revealed that the shrimp feed prices were increased up, then please clarity following questions												
	- Average shrimp feed prices increased from normal (Baht/bag)	28		40		34		20		20		55	
	- Exchange the shrimp feed from normal to lower grade to save the cost												
	- Yes	12	24	11	42	7	32	1	20	1	33	0	0
	- No	38	76	15	58	15	68	4	80	2	67	3	100
4.15	What are consequences from the worst flood and level of the damage ran												
	4.15.1 Mass escape and dead from the flooding												
	- High	47	94	20	77	15	68	5	100	2	67	2	67
	- Medium	3	6	2	8	7	32	0	0	1	33	1	33
	- Low	0	0	4	15	0	0	0	0	0	0	0	0
	4.15.2 Pollutions and unknown sediment accumulated												

	in the pond during flooding cause the reduction of shrimp production in the next crop												
	- High	34	68	17	65	16	73	0	0	2	67	0	0
	- Medium	13	26	6	23	5	23	3	60	1	33	0	0
	- Low	3	6	3	12	1	5	2	40	2	67	3	100
4.15.3	Facility and equipments i.e. paddle wheel aerator, motor, feed storage were damaged by the flooding and difficulte to repair												
	- High	37	74	8	31	12	55	0	0	2	67	1	33
	- Medium	8	16	6	23	8	36	0	0	0	0	1	33
	- Low	5	10	12	46	2	9	5	100	1	33	1	33
4.15.4	Soil quality and enrichment are degraded and affect to shrimp production												
	- High	12	24	8	31	2	9	1	20	2	67	0	0
	- Medium	31	62	8	31	12	55	1	20	1	33	2	67
	- Low	7	14	10	38	8	36	3	60	0	0	1	33
4.15.5	Effect from sediment and organic matter that accumulated in the pond cause the reduction of shrimp production in the next crop												
	- High	23	46	9	35	12	55	2	40	0	0	0	0
	- Medium	22	44	10	38	9	41	1	20	2	67	3	100
	- Low	5	10	7	27	1	5	2	40	1	33	0	0
4.15.6	Dike of pond and bottom of pond are required more time to recover												

- High	32	64	9	35	4	18	1	20	1	33	0	0
- Medium	12	24	11	42	12	55	4	80	2	67	1	33
- Low	6	12	6	23	6	27	0	0	0	0	2	67
5. Mitigation and preventive action undertaken to cope with past flood												
5.1 Have you ever prepared and implemented to cope and mitigate the effect from flooding?												
- Yes	43	86	19	73	19	86	4	80	3	100	3	100
- No	7	14	7	27	3	14	1	20	0	0	0	0
5.2 If you have ever undertaken to cope with flood, what you have done and did it work?												
- Put the net around the pond to prevent the escape of shrimp	34	79	16	84	17	89	3	75	3	100	3	100
- Completely prevetion the effect from floods	7	21	2	13	3	18	1	33	0	0	0	0
- Partial prevention the effect from floods	24	71	10	63	11	65	2	67	3	100	3	100
- Not capable to prevent the effect from floods	3	7	4	21	3	16	0	0	0	0	0	0
- Cover the surface soil to increase the height of dike	23	53	11	58	12	63	4	100	2	67	3	100
- Completely prevetion the effect from floods	2	9	1	9	2	17	3	75	0	0	0	0
- Partial prevention the effect from floods	15	65	6	55	9	75	1	25	2	100	3	100
- Not capable to prevent the effect from floods	6	26	4	36	1	8	0	0	0	0	0	0

- Early harvest before the flood occurred	8	19	12	63	3	16	1	25	2	67	3	100
- Completely prevetion the effect from floods	1	13	2	17	1	33	0	0	0	0	0	0
- Partial prevention the effect from floods	5	63	10	83	0	0	1	100	2	100	3	100
- Not capable to prevent the effect from floods	2	25	0	0	2	67	0	0	0	0	0	0
5.3 Average the net price used for putting around the pond (Thai Baht)	3755		4138		2760		3250		4600		7633	
5.4 Average cost for hiring the excavator to make the dike of 1 pond high enough (Baht)	38765		10919		22845		11333		45333		5000	
5.5 Did cost for engaging the excavator during the flooding higher than the normal situation?												
- Yes	21	91	15	79	9	75	3	75	2	100	2	67
- No	2	9	4	21	3	25	1	25	0	0	1	33
5.6 Is there any difficulty while you were hiring the excavator before flooding?												
- Yes	19	83	6	32	11	92	1	25	1	50	0	0
- No	4	17	13	68	1	8	3	75	1	33	3	100
5.7 Have you ever undertaken the mitigation actions to cope with floods with your neighbor shrimp farmers												
- Yes	4	8	1	4	2	9	0	0	0	0	0	0

- No	46	92	25	96	20	91	5	100	3	100	3	100
5.8 Have you ever been received the suggestion and guideline from relevant authorities to cope with flood?												
- Yes	6	12	2	8	4	18	0	0	0	0	0	0
- No	44	88	24	92	18	82	5	100	3	100	3	100
5.9 What was the source of funding used to cope with flooding?												
- Supported by government or others	2	4	0	0	0	0	0	0	0	0	0	0
- Own financial aid	48	96	26	100	22	100	5	100	3	100	3	100
5.10 From the last flooding on your shrimp farm, have you ever been informed in advance about the flooding to be occurred on your shrimp farm?												
- Yes	43	86	21	81	21	95	5	100	2	67	3	100
- From annoucement of governments	23	53	13	62	19	90	2	40	0	0	2	67
- From newspaper	0	0	0	0	0	0	3	60	2	100	2	67
- From neighbor shrimp farmers	18	42	6	29	2	10	0	0	2	100	2	67
- From visual inspection by yourself	2	5	2	10	0	0	0	0	2	100	3	100
- No	7	14	5	19	1	5	0	0	1	33	0	0
5.11 After the flooding, have you recovered your shrimp												

	pond that required more practices than ever?												
	- Yes	43	86	22	85	11	50	4	80	1	33	2	67
	- No	7	14	4	15	11	50	1	20	2	67	1	33
5.12	If you answered "yes" in question 5.11, what you have done for recovering your shrimp pond after flooding												
	- Remove golden apple snail	34	79	14	64	4	36	0	0	0	0	0	0
	- Throw lime in higher amount than ever	3	7	2	9	3	27	0	0	1	100	1	50
	- Leave the pond before new stocking longer	5	12	2	9		0	0	0		0	0	0
	- Apply probiotic for removal of sludge and organic matters		0		0		0	0	0		0	0	0
	- Apply fertilizer in higher amount than ever	1	2	4	18	4	36	0	0	0	0	0	0
	- Repair the dike of pond	0	0		0		0	4	100	0	0	1	50
5.13	Average costs for recovery after flooding (Thai Baht)												
5.14	Where did the budget for recovery come from?												
	- Supported by government i.e. DOF	26	52	12	46	5	23	0	0	0	0	0	0
	- Own financial aid	6	12	3	12	22	100	5	100	2	67	3	100
	- Supported by other funding source	18	36	11	42	0	0	0	0	1	33	0	0
5.15	How long did you take for recovery your shrimp pond after the flooding (month)	3		3		3		2		4		2	

6. Perspective of shrimp farmers on future flood and weather variable												
6.1 Based on your experience, where do you think it is most susceptible to flood if shrimp farms are located? and level of susceptible to flood range from high, medium, low and none												
- Shrimp farms located in Bangpakong river banks and tributary banks												
- High susceptible to flood	23	46	11	42	2	9	4	80	3	100	3	100
- Medium susceptible to flood	11	22	8	31	2	9	0	0	0	0	0	0
- Low susceptible to flood	16	32	2	8	18	82	0	0	0	0	0	0
- None	0	0	5	19	0	0	0	0	0	0	0	0
- Can't make a decision	0	0	0	0	0	0	1	20	0	0	0	0
- Shrimp farms located nearby Khao Yai or Prachantakham and Nadee distirct of Prachinburi												
- High susceptible to flood	22	44	18	69	11	50	2	40	1	33	2	67
- Medium susceptible to flood	24	48	4	15	4	18	1	20	1	33	0	0
- Low susceptible to flood	4	8	2	8	4	18	0	0	1	33	0	0
- None	0	0	0	0	3	14	0	0	0	0	1	33
- Can't make a decision	0	0	0	0	0	0	2	40	0	0	0	0
- Shrimp farm located in the east side of Bangpakong river or near Bangkok												
- High susceptible to flood	22	44	21	81	2	9	2	40	0	0	2	67
- Medium susceptible to flood	11	22	2	8	8	36	2	40	0	0	1	33
- Low susceptible to flood	0	0	0	0	0	0	0	0	1	33	0	0
- None	2	4	0	0	4	18	0	0	2	67	0	0

	- Can't make a decision	15	30	3	12	8	36	1	20	0	0	0	0
	- Shrimp farms located nearby road no. 304												
	- High susceptible to flood	11	22	2	8	3	14	1	20	0	0	0	0
	- Medium susceptible to flood	2	4	2	8	4	18	1	20	2	67	0	0
	- Low susceptible to flood	0	0	0	0	0	0	0	0	0	0	0	0
	- None	14	28	2	8	2	9	0	0	1	33	1	33
	- Can't make a decision	13	26	20	77	13	59	3	60	0	0	2	67
6.2	Based on your experience, is there any consequence from climate change or weather variable? Please range the level of change into 5 levels												
	- Heavy rainfall for several days												
	- Very high change	37	74	21	81	18	82	1	20	0	0	2	67
	- High change	12	24	2	8	3	14	4	80	1	33	1	33
	- Medium change	1	2	3	12	1	5	0	0	2	67	0	0
	- Low change	0	0	0	0	0	0	0	0	0	0	0	0
	- Very low change	0	0	0	0	0	0	0	0	0	0	0	0
	- Frequency of floods increasing												
	- Very high change	33	66	21	81	19	86	1	20	0	0	1	33
	- High change	17	34	2	8	2	9	0	0	1	33	2	67
	- Medium change	0	0	3	12	1	5	4	80	2	67	0	0
	- Low change	0	0	0	0	0	0	0	0	0	0	0	0
	- Very low change	0	0	0	0	0	0	0	0	0	0	0	0
	- Frequency of drough increasing												
	- Very high change	12	24	4	15	2	9	1	20	0	0	0	0
	- High change	20	40	2	8	11	50	1	20	0	0	0	0
	- Medium change	8	16	8	31	0	0	3	60	2	67	3	100
	- Low change	5	10	8	31	9	41	0	0	1	33	0	0
	- Very low change	5	10	4	15	0	0	0	0	0	0	0	0

- Prolonged period of cold weather												
- Very high change	0	0	0	0	0	0	0	0	0	0	0	0
- High change	2	4	0	0	0	0	0	0	0	0	1	33
- Medium change	12	24	8	31	12	55	0	0	2	67	0	0
- Low change	2	4	4	15	10	45	0	0	0	0	2	67
- Very low change	34	68	14	54	0	0	5	100	1	33	0	0
6.3 From the weather variable answered in question 6.2, do you think each change affect to your shrimp farm?												
- Heavy rainfall for several days												
- Positive impact on shrimp farm	0	0	0	0	0	0	0	0	0	0	0	0
- Negative impact on shrimp farm	43	86	22	85	22	100	4	80	2	67	2	67
- No impact on shrimp farm	7	14	4	15	0	0	1	20	1	33	1	33
- Insufficient water in canals for pumping to store in the shrimp pond												
- Positive impact on shrimp farm	0	0	0	0	0	0	0	0	0	0	0	0
- Negative impact on shrimp farm	45	90	26	100	22	100	1	20	0	0	1	33
- No impact on shrimp farm	5	10	0	0	0	0	4	80	3	100	2	67
- Variable of rainfall intensity, frequency and amount are increased												
- Positive impact on shrimp farm	0	0	0	0	0	0	0	0	0	0	0	0
- Negative impact on shrimp farm	43	86	22	85	21	95	4	80	2	67	2	67
- No impact on shrimp farm	7	14	4	15	1	5	1	20	1	33	1	33
- Quality of surface water has decreased												
- Positive impact on shrimp farm	0	0	0	0	0	0	0	0	0	0	0	0
- Negative impact on shrimp farm	47	94	22	85	22	100	2	40	3	100	1	33
- No impact on shrimp farm	3	6	4	15	0	0	3	60	0	0	2	67

- Increase the flood risk												
- Positive impact on shrimp farm	0	0	0	0	0	0	0	0	0	0	0	0
- Negative impact on shrimp farm	49	98	26	100	20	91	4	80	2	67	2	67
- No impact on shrimp farm	1	2	0	0	2	9	1	20	1	33	1	33
- Increase of dought												
- Positive impact on shrimp farm	0	0	0	0	0	0	0	0	0	0	0	0
- Negative impact on shrimp farm	34	68	21	81	17	77	4	80	1	33	1	33
- No impact on shrimp farm	16	32	5	19	5	23	1	20	2	67	2	67
- Salt water intrusion												
- Positive impact on shrimp farm	4	8	7	27	2	9	0	0	1	33	0	0
- Negative impact on shrimp farm	20	40	11	42	20	91	3	60	0	0	0	0
- No impact on shrimp farm	26	52	8	31	0	0	2	40	2	67	3	100
6.4 What are results caused by floods that made change on shrimp rearing/practices?												
- Spend a lot of time for recovery which lead to loss of investment opportunity												
- Very high impact	12	24	8	31	8	36	0	0	0	0	1	33
- High impact	24	48	12	46	8	36	0	0	2	67	0	0
- Medium impact	22	44	2	8	6	27	5	100	1	33	2	67
- Low impact	6	12	2	8	0	0	0	0	0	0	0	0
- Very low impact	0	0	4	15	0	0	0	0	0	0	0	0
- Spend a lot of time for preparing the water in the pond until it is ready for releasing shrimp fry												
- Very high impact	22	44	11	42	3	14	0	0	0	0	0	0
- High impact	11	22	12	46	12	55	0	0	2	67	0	0

- Medium impact	17	34	3	12	7	32	5	100	1	33	3	100
- Low impact	0	0	0	0	0	0	0	0	0	0	0	0
- Very low impact	0	0	0	0	0	0	0	0	0	0	0	0
- Crop calendar has shiefted as a result of flooding												
- Very high impact	23	46	4	15	4	18	0	0	0	0	0	0
- High impact	2	4	18	69	9	41	0	0	1	33	0	0
- Medium impact	14	28	2	8	2	9	3	60	2	67	2	67
- Low impact	11	22	2	8	7	32	0	0	0	0	0	0
- Very low impact	0	0	0	0	0	0	2	40	0	0	1	33
- Annaul production or crop cycle has decreased												
- Very high impact	12	24	4	15	2	9	0	0	0	0	0	0
- High impact	11	22	2	8	4	18	0	0	0	0	0	0
- Medium impact	23	46	20	77	12	55	5	100	3	100	2	67
- Low impact	4	8	0	0	4	18	0	0	0	0	1	33
- Very low impact	0	0	0	0	0	0	0	0	0	0	0	0
- Weight of harvested shrimp has decreased when comparing to the previous crop before flooding												
- Very high impact	3	6	1	4	0	0	0	0	0	0	0	0
- High impact	11	22	8	31	2	9	0	0	0	0	0	0
- Medium impact	34	68	13	50	19	86	5	100	3	100	2	67
- Low impact	2	4	4	15	1	5	0	0	0	0	0	0
- Very low impact	0	0	0	0	0	0	0	0	0	0	1	33
7. Adaptation measures to be undertaken in the next 5 years												
7.1 What do you plan to do in the next 3 years and its effective for coping with flood?												

7.1.1	Protecting shrimp farm structures from floods by												
	- Increasing the height of pond dike												
	- To be done within 3 years	32	64	18	69	2	9	4	80	2	67	3	100
	- Not plan ahead	18	36	8	31	20	91	1	20	1	33	0	0
	- Believe this implementation can protect the fram 100% from floods	13	41	12	67	1	50	0	0	1	50	0	0
	- Believe this implementation can protect the farm partially	19	59	6	33	1	50	0	0	1	50	0	0
	- Working together with nearby shrimp farmers and communities if your shrimp farm is not located individually												
	- To be done within 3 years	2	4	1	4	2	9	1	20	0	0	1	33
	- Not plan ahead	28	56	12	46	20	91	4	80	3	100	2	67
	- Believe this implementation can protect the fram 100% from floods	2	100	0	0	0	0	0	0	0	0	0	0
	- Believe this implementation can protect the farm partially	0	0	1	100	2	100	1	100	0	0	1	100
7.1.2	Action plans for preventing the damage from flood by applying following techniques												
	- Put the net around the pond to prevent the escape of shrimp												
	- To be done within 3 years	38	76	23	88	18	82	3	60	2	67	1	33
	- Not plan ahead	12	24	3	12	4	18	2	40	1	33	2	67
	- Believe this implementation can protect the fram 100% from floods	14	37	15	65	15	83	0	0	1	50	0	0
	- Believe this implementation can protect the	14	37	8	35	3	17	3	100	1	50	1	100

farm partially												
- Early harvest before the floods occurred												
- To be done within 3 years	34	68	5	19	2	9	3	60	2	67	1	33
- Not plan ahead	16	32	21	81	20	91	2	40	1	33	2	67
- Believe this implementation can protect the fram 100% from floods	20	59	4	80	1	50	1	33	1	50	0	0
- Believe this implementation can protect the farm partially	14	41	1	20	1	50	2	67	1	50	1	100
- Change the species that can tolerate on the weather change or impacts from floods												
- To be done within 3 years	0	0	0	0	0	0	0	0	0	0	0	0
- Not plan ahead	50	100	26	100	22	100	5	100	3	100	3	100
- Believe this implementation can protect the fram 100% from floods	0	0	0	0	0	0	0	0	0	0	0	0
- Believe this implementation can protect the farm partially	0	0	0	0	0	0	0	0	0	0	0	0
7.1.3 Managing and adapting the practices												
- Change the calendar of shrimp rearing in order to ensure that the harvesting time can be done before the occurrence of floods												
- To be done within 3 years	12	24	4	15	2	9	3	60	1	33	2	67
- Not plan ahead	38	76	22	85	20	91	2	40	2	67	1	33
- Believe this implementation can protect the fram 100% from floods	4	33	2	50	1	50	1	33	1	100	1	50
- Believe this implementation can protect the farm partially	8	67	2	50	1	50	2	67	0	0	1	50

	- Improve the channel to access the information of flood warning and forecasting												
	- To be done within 3 years	13	26	12	46	14	64	3	60	2	67	3	100
	- Not plan ahead	37	74	14	54	8	36	2	40	1	33	0	0
	- Believe this implementation can protect the fram 100% from floods	4	31	6	50	4	18	0	0	2	100	1	33
	- Believe this implementation can protect the farm partially	9	69	6	50	10	71	3	100	0	0	2	67
7.1.4	Improving access to financial source												
	- Find flood insurance from the banks and relevant agencies												
	- To be done within 3 years	2	4	1	4	2	9	2	40	0	0	1	33
	- Not plan ahead	48	96	25	96	20	91	3	60	3	100	2	67
	- Believe this implementation can protect the fram 100% from floods	1	50	0	0	0	0	0	0	0	0	0	0
	- Believe this implementation can protect the farm partially	1	50	1	100	2	100	2	100	0	0	1	100
	- Find a financial provider for investment to build or construct the facility to cope with flooding												
	- To be done within 3 years	11	22	2	8	3	14	1	20	0	0	1	33
	- Not plan ahead	39	78	24	92	19	86	4	80	3	100	2	67
	- Believe this implementation can protect the fram 100% from floods	2	18	0	0	0	0	0	0	0	0	1	100
	- Believe this implementation can protect the farm partially	9	82	2	100	3	100	1	100	0	0	0	0

7.2 What are reasons supporting your decision to think in investing and implementing to cope with flood in the next 3 years												
- Based on your assessment and experience, you believe that the climate change will increase the frequency and intensity of rainfall	4	8	2	8	1	5	0	0	2	67	2	67
- You were knowed that your shrimp farm areas are defined as the susceptible area to flood	13	26	8	31	9	41	0	0	0	0	1	33
- Association or governments that you familiar with have suggested you to plan for cope with flood	0	0	0	0	0	0	0	0	0	0	0	0
- Don't want to change to new career and want to do the shrimp farming	33	66	16	62	12	55	5	100	1	33	1	33
8. Further required information for supporting in making a decision												
8.1 Did you know there is accessible information to help you in making a decision to manage and implement to cope with floods?												
- Shrmp farm areas that are susceptible to floods or flood hazard map												
- Yes	8	16	3	12	2	9	0	0	1	33	1	33
- No	42	84	23	88	20	91	5	100	2	67	2	67
- Guideline or best practices to adapt on flood												

occurrence												
- Yes	2	4	3	12	1	5	0	0	2	67	1	33
- No	48	96	23	88	21	95	5	100	1	33	2	67
8.2 If you could access information mentioned in 8.1, do you want to get these information?												
- Shrmp farm areas that are susceptible to floods or flood hazard map												
- Yes	32	64	24	92	18	82	4	80	2	67	2	67
- No	18	36	2	8	4	18	1	20	1	33	1	33
- Guideline or best practices to adapt on flood occurrence												
- Yes	43	86	19	73	21	95	4	80	2	67	2	67
- No	7	14	7	27	1	5	1	20	1	33	1	33
8.3 What is the most important for you to use for making adaptation practices to cope or minimize the impacts from flooding? Range from the score if most wanted (1) until less wanted (3)												
- Budget	2		2		2		1		2		3	
- Guideline or best practices for adaptation to cope and minimize the impact from flood	2		2		2		2		2		1	
- Information on flood forecasting	2		2		2		3		2		2	

JOURNAL PUBLICATION AND PROCEEDING

Seekao, C. and Pharino, C. Assessment of shrimp farming vulnerability towards floods using multicriteria evaluation and GIS: Case study Bangpakong Sub-Basin in Thailand. Environmental Earth Science (Under revision).

Seekao, C. and Pharino, C. Key factors affecting the flood vulnerability and adaptation of the shrimp farming sector in Thailand. International journal disaster risk science (Under consideration).

Seekao, C. and Pharino, C. Cost-benefit analysis of shrimp farming's flood risk reduction strategies in Thailand. Flood risk management (Under consideration).

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Seekao, C., Pharino, C., 2013. Using multi-criteria evaluation (MCE) and geographic information system (GIS) for assessing flood vulnerable area of shrimp farm in Chachoengsao province. In: Proceeding of the International Conference of Environmental and Hazardous Substance Management towards a Green Economy, pp 97-98.

VITA

Chaiyaporn Seekao was born on June 6, 1978 in Singburi, Thailand. He grew up in SIngburi, eventually studying at Singburi School, a public high school. He attended Fishery Faculty of Kasetsart University from 1996 to 2002, and graduated with a Bechelor of Science degree in Fisheries Management. After undergraduate school, the author spent four years working at Department of Fisheries of Thailand. There, it was his privilege to build up and productive relationship with experts in Department of Fisheries. Later, he pursued his Master's Degree in Sustainable Land Use and Natural Resource Management Program at Kasetsart University during 2005-2006. While studying, he was also working with Food and Agriculture Organization of the United Nations. After postgraduate school, the author spent for five years working at Bio Solution International Co., Ltd and Team Consulting Engineering and Management Co., Ltd.

In 2010, he entered the Ph.D. international Program in Environmental Management, Center of Excellence on Hazardous Substance Management (HSM), Chulalongkorn University. At Chulalongkorn University, he attended conferences for publication of his research and found that vulnerability and adaptation assessment is now emerging. Studying on this issue led the author directly to interest in future problems with shrimp farming, which was related to his background.