FARMERS' PERCEPTIONS AND STRATEGIES TOWARDS A CHANGING CLIMATE IN PERI-URBAN AQUACULTURE: A CASE STUDY OF THANH TRI DISTRICT, HANOI, VIETNAM

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มุมมองและยุทธศาสตร์เกษตรกรต่อการเปลี่ยนแปลงภูมิอากาศในการเพาะพันธุ์สัตว์น้ำ
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นางสาวเหวียน ง็อก ฮวง

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Thesis Title	FARMERS' PERCEPTIONS AND STRATEGIES TOWARDS A CHANGING CLIMATE IN PERI-URBAN AQUACULTURE: A CASE STUDYOF THANH TRI DISTRICT, HANOI, VIETNAM
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เหวียน ง็อก ฮวง : มุมมองและยุทธศาสตร์เกษตรกรต่อการเปลี่ยนแปลงภูมิอากาศในการเพาะพันธุ์สัตว์น้ำของพื้นที่กึ่งเมือง : กรณีศึกษาจังหวัดทันฮ์ ทริ ฮานอย ประเทศเวียดนาม (FARMERS' PERCEPTIONS AND STRATEGIES TOWARDS A CHANGING CLIMATE IN PERI-URBAN AQUACULTURE: A CASE STUDYOF THANH TRI DISTRICT, HANOI, VIETNAM) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร.จักรกริช สังขมณี, 104 หน้า.

การเปลี่ยนแปลงและความผันผวนของสภาพภูมิอากาศก่อให้เกิดความเสี่ยงและผล กระทบต่อกิจกรรมการผลิตทางธรรมชาติ ซึ่งรวมไปถึงการเพาะพันธุ์สัตว์น้ำ การศึกษานี้มุ่งหวังที่จะศึกษามุมมองของเกษตรกรที่มีต่อความผันผวนและผล กระทบของสภาพภูมิอากาศ และความสัมพันธ์ระหว่างมุมมองและการปรับตัวของเกษตรกร งานวิจัยนี้มุ่งเน้นถึงมุมมองและยุทธศาสตร์ที่เกษตรกรเพาะพันธ์สัตว์น้ำใน พื้นที่กึ่งเมืองประยุกต์ใช้ในเขตทันฮ์ทริ ฮานอย ภายใต้บริบทของการเปลี่ยนแปลงสภาพภูมิอากาศและการขยายตัวของชุมชนเมืองจาก การศึกษาพบว่าเกษตรกรเพาะพันธ์สัตว์น้ำในพื้นที่กึ่งเมืองมีความกังวลเกี่ยว กับความผันผวนของสภาพภูมิอากาศในพื้นที่โดยเฉพาะอย่างยิ่งอุณหภูมิ การเปลี่ยนแปลงของปริมาณน้ำฝน ความถี่ และความรุนแรงของสภาพภูมิอากาศสุดขั้ว อย่างไรก็ดีจากการสัมภาษณ์เกษตรกรส่วนใหญ่มีการพึ่งพาสภาพภูมิอากาศระยะสั้นแทนที่การพึ่งพาการเปลี่ยนแปลงภาพอากาศระยะยาว นอกจากนี้ผลการศึกษายังแสดงให้เห็นว่าเกษตรกรที่เพาะพันธุ์สัตว์น้ำในขนาด ที่ต่างกันมีความตระหนักถึงผลกระทบของความเปลี่ยนแปลงในระดับที่แตกต่างกัน โดยเกษตรกรที่เพาะพันธุ์สัตว์น้ำในขนาดเล็กเสี่ยงต่อการได้รับผลกระทบจากการเปลี่ยนแปลงของสภาพภูมิอากาศมากกว่าเมื่อเทียบกับการเพาะพันธุ์สัตว์น้ำใน ขนาดอื่นๆ นอกจากนี้ผลกระทบจากความผันผวนของสภาพภูมิอากาศยังส่งผลดีและผลเสียต่อ เกษตรกร และผลกระทบยังถูกทำให้รุนแรงขึ้นโดยปัจจัยที่ไม่เกี่ยวข้องกับสภาพภูมิอากาศ เช่น การขยายตัวของชุมชนเมือง ในการจัดการกับความเปลี่ยนแปลงสภาพภูมิอากาศและผลกระทบจากความเปลี่ยนแปลง นั้นเกษตรกรส่วนมากใช้ยุทธศาสตร์ที่ประยุกต์ขึ้นเองจากประสบการณ์ตรง และมีความตึงเครียดในการใช้น้ำและการถือครองที่ดินเป็นสองอุปสรรคสำคัญที่ลด ความสามารถของเกษตรกรในการปรับตัวให้เข้ากับสภาพอากาศที่เปลี่ยนแปลง

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NGUYEN NGOC HUONG: FARMERS' PERCEPTIONS AND STRATEGIES TOWARDS A CHANGING CLIMATE IN PERI-URBAN AQUACULTURE: A CASE STUDYOF THANH TRI DISTRICT, HANOI, VIETNAM. ADVISOR: ASST. PROF. JAKKRIT SANGKHAMANEE, Ph.D., 104 pp.

Climate change and variability poses serious risks and impacts on natural-based production activities including aquaculture. Little studies have been devoted to discovering how farmers perceive climate variability and its impacts and the relationship between the perceptions and adaptive responses. This research focuses on the perceptions and strategies of peri-urban fish farmers at different farming scales in the Thanh Tri District, Hanoi in a context of changing climate and urbanization. The study found out that peri-urban fish farmers have an increasing concern about local climate variability, especially in temperature, rainfall variability and frequency and intensity of extreme climatic events. However, most of interviewed farmers relied on recent climate variability in short-term instead of long-term changes in climate. Furthermore, the results show that farmers at different farming scales perceived different degree of climate variability impacts. Small-scale farms are perceived to affect most from the changes in climate variability and become the most vulnerable to those changes comparing to others scales. Besides, impacts from climate variability affect both negatively and positively to farmers and are exacerbated by non-climate factors including urbanization. Farmers mainly use autonomous adaptive strategies based on personal experience in order to response to changes in climate and its impacts. Water stress and land tenure are identified as two key barriers for farmers to decline adaptive capacity in a changing climate.

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CHAPTER I
INTRODUCTION

1.1. Research Background

Climate change is one of the major phenomena that have captured special global attention. Climate change is expected to cause the increase in temperature all over the globe with a warming of 0.85 (0.65°C to 1.06°C) over the period 1880 to 2012 (Hartmann et al., 2013, p. 32). Simultaneously, the global precipitation increased by around 1% in the last few decades, but significantly spatial variability (Fox & Seielstad, 2003). According to Intergovernmental Panel on Climate Change (IPCC), while in tropical areas, the rainfall per decade increased from 0.2 to 0.3%, rainfall in sub-tropical areas decreased by 0.3% per decade (IPCC, 2007). Developing countries are likely to be significantly affected from these changes due to large number of population living in exposed areas, dependence directly on natural resources for their livelihoods and limited institutional capacities to take proactive measures (Adger, 1999). Thus, climate change poses a serious impact on natural-based production activities such as agriculture, fisheries and aquaculture.

Vietnam, with a typical tropical monsoon climate, is predicted as one of the most vulnerable countries to impact significantly from climate change due to long coastlines and a heavy reliance on agriculture and natural resource (World Bank, 2009). Particularly, two concentrated population 'mega-deltas' including the Mekong and Red River Deltas which produce and supply most of the food for domestic consumption and export are expected to affect most from climate change impacts (IFAD, 2014). The country has experienced changes of climate parameters and sea level with noticeable increases in average annual temperatures; variability of both rainfall and temperature between years and within seasons; and a likely increased occurrence of higher intensity storms (IFAD, 2014; MONRE, 2009). Furthermore, climate change scenarios for the country suggest that impacts are likely to derive primarily from rising sea levels and changes in rainfall and temperatures (IFAD, 2014; MONRE, 2008, 2009).

Climate change is expected to have a considerable impact on fisheries and aquaculture sector, which accounted for 6.6% of the national GDP (2008). Climate change will affect aquaculture through gradual warming, ocean acidification, changes in the frequency, intensity, and location of climate patterns and extreme events, and changes in precipitation with associated changes in groundwater and river flows (IPCC, 2014, FAO 2009a). The effects of climate change on aquaculture systems and production can be various, namely increasing water temperature, decreasing oxygen levels and ascending the toxicity of pollutants.

1.2. Research Problem

Hanoi belonged to Red River Delta with population of over 6.4 million people has experienced the fastest growth at a pace of more than 4% per year (UNDESA, 2012), which together increase the food demand for growing population. Aquaculture in peri-urban Hanoi provides a source of nutritious and affordable food to increasing urban consumers. While 10-20% of freshwater fish consumed in Hanoi comes from peri-urban production, as the cultivation of aquatic vegetables in peri-urban meet almost 100% of demand for vegetables of urban consumers (van den Berg, van Wijk, & Van Hoi, 2003). Furthermore, aquatic production also plays an important role in providing incomes and livelihoods for farmers in peri-urban Hanoi (T. D. P. Nguyen & Pham, 2005). More notably, aquaculture has been considered as a strategy in greening the city while recycling wastewater. Because conventional treatment of urban wastewater is often not an option for fast growing cities in developing countries, aquatic production systems could be the solution of treating wastewater effectively, while reusing both nutrients and water and, thus overall contribute to greener cities. Provided that public health issues are addressed, aquaculture systems can be both cost effective and a practical low-cost treatment alternative (PAPUSSA, 2006).

The process of urban growth has had negative overall effect on food production and thus aquaculture in cities. For peri-urban aquaculture, access to land is one of the main requirements for producing fish (Leschen, Little, & Bunting, 2005). Unlikely peri-urban agriculture which can be successful produced in small areas of marginal land in cities, the prospective fish farmers have to not only find and retain access to the necessary area of land, but also obtain a source of water that is reliable both in terms of seasonal availability and quality. In Hanoi, although urban demand for food production, especially freshwater fish increases, the agriculture land has tended to decline for the use of built-up areas (van den Berg et al., 2003). Therefore, in order to meet the demand of urban consumption with the limited area for farming, the farmers need to intensify their production systems require more chemicals, pesticides and fertilizers to increase productivity. Besides, population growth together with the increase of urban wastewater, especially domestic wastewater likely causes the risk in production and health for farmers dependence largely on wastewater for aquatic production. The decrease in water quality might reduce the quality of fish with a bad smell and taste (Edwards, 2005). While the demand for large fish in urban increases, small fish raised in ponds using wastewater are difficult to market in Hanoi, thus mainly catch the demand of low-income consumers. Another important concern for aquaculture production systems using wastewater is to minimize the negative risks on human health such as skin problems and helminth infections (WHO, 2006). Furthermore, decreasing water quality also affect to fish as well. In a study of fish ponds using wastewater in peri-urban areas in Hanoi, it is found out that fish raised in these aquaculture systems are at risk of infection with fishborne zoonotic trematode (FZT), which can be transmitted to humans through consumption of raw or improperly prepared fish (Hop, De, Murrell, & Dalsgaard, 2007).

During the urbanization process, Hanoi experience an increase trend in the annual air temperature (Tran, Kubota, & Trihamdani, 2015). The average annual air temperature recorded from 1980 to 2010 increased by 1.5°C in the city comparing to the ascending of 0.5°C in the surrounding rural areas. It is also concluded that there is the existence of urban heat islands effect, where city several degrees warmer than country sides, as a result of the rapid urbanization in Hanoi (Trihamdani et al., 2014).

Urban growth leads to dramatic land use changes and growth in energy consumption demand, which affects to urban climate. Due to the urban expansion, 28% of Hanoi city's natural land will be allocated for the urban construction by 2030. Thus, the total build-up areas would dramatically ascend to almost three times from 46,340 ha (14%) to more than 129,500 ha (39%) (Tran et al., 2015). Besides, the population of the city is forecasted to reach over 9 million people by 2030 with urbanization rate of 65-68% (Tran et al., 2015). Population growth with higher living standards in urban areas results in a large increase in energy consumption. It is predicted that high air temperature areas at 40-41°C, would expand broadly in the built-up areas (Tran et al., 2015). In Hanoi, almost the built-up land is completely spread around the city but not in the center itself, thus peri-urban areas around the cities prone to affect from the changes in urban climate (Van Dijk et al., 2013). Furthermore, belongs to the Red River Delta, Hanoi is also threaten by floods, in which agriculture and aquaculture land might be affected (Van Dijk et al., 2013).

In fact, peri-urban aquaculture production in Hanoi concentrated on Thanh Tri District with the total contribution of 52% of fish production in the city (Anh et al., 2007; Hop et al., 2007). Because the district lies in lowest land area in the city, which creates the favorable condition for aquaculture production due to easily access to water resources. Water sources of aquaculture are rivers which receive wastewater from sewage network and storm or rain water in rainy season. Thanh Tri District lies downstream of To Lich river system consisting of the four rivers Kim Nguu, Set, Lu and To Lich where receives mostly untreated wastewater from Hanoi (Q. T. Nguyen, 2001). While the concern of reducing wastewater quality in accordance with the dominant trends for annual rainfall in Vietnam as well as in Hanoi significantly decrease, the aquaculture production in the district is prone to water stress. Further, the changes in water temperature in ponds and farms might be affected from the rising temperature trend in the city and built-up areas due to the land use change. More important, although the district is functioned as the harmony the urban climate because of large numbers of ponds and lakes in the area, the aquaculture production in the area are considered to be more vulnerable to the climate change impacts than other area such as heavy rain leadings to flooding since it situated in low land.

Although developing countries are confronting climate variability which challenges natural-based production activities including aquaculture and farmers' livelihoods, little studies has been devoted to discovering how farmers perceive climate variability and its impacts and the relationship between the perceptions and adaptive responses (Dang, 2014). Therefore, the research exploresthe changes in climate of the district by analyzing the climatic records and peri-urban fish farmer's perception on the climate change. In addition, the study addresses the impacts of climate change on aquaculture as experienced by the peri-urban fish farmers in the area. Lastly, the research investigates the adaptive strategy that peri-urban fish farmers respond to the change and its impacts.

The thesis consists of 5 chapters. Chapter 1 states the research problem; identifies the research questions and objectives; illustrates conceptual framework and describes research methodology and its constraints as well as significances. Chapter 2 reviews key concepts and approaches which are used to analyzed and discussed in the next chapter and points out the knowledge gap. Chapter 3 describes key background of study areas and analyzes the farmers' perceptions on climate variability. Chapter 4 investigates and discusses the perceived impacts of climate variability and adaptive strategies as well as adaptive capacity of farmers and community to response to changes. Last chapter presents the conclusion, recommendation and gives suggestion for future research.

1.3. Research Questions

The study aims to answer these questions:

- What are farmers' perceptions of changes in climate variability?
- How do farmers perceive the impacts of changes in climate variability on aquaculture production?
- What are adaptive strategies do the fish farmers response to the changes in climate variability and its impacts?
- How adaptive capacity of farmers affect to their adaptive strategies to those changes and impacts?

1.4. Research Objectives

The main objectives of the research are:

- To explore the changes in climate variability by analyzing climatic records and fish farmers' perception in Thanh Tri district;
- To address the impacts of changes in climate variability on aquaculture production based on fish farmer's perceptions;
- To investigate the adaptive strategies that fish farmers response to those changes and impacts;
- To explore adaptive capacity of fish farmers and its influence to their adaptive strategies to response to the changes and impacts.

1.5. Conceptual Framework

The illustrated conceptual framework (Figure 1) proposes to examine how farmer's perceptions of changes in climate variability and its impacts affect to their adaptive strategies. The changes in climate variability which focuses on analyzing changes in temperature variability, rainfall variability and extreme climatic events are addressed based on institutional knowledge and perceptions of fish farmers. With the main theme of the study focusing on the farmer's perceptions, the research investigates the perceived impacts on aquaculture systems and addresses adaptive strategies to those impacts. Furthermore, those consequences are caused by not only climate factors but also non-climate factors, particularly external stresses from urbanization, which exacerbate the impacts of changing climate. Thus, the study examines how these stresses in combination with community and individual adaptive capacity influence to the ways fish farmers adapt to climate change.

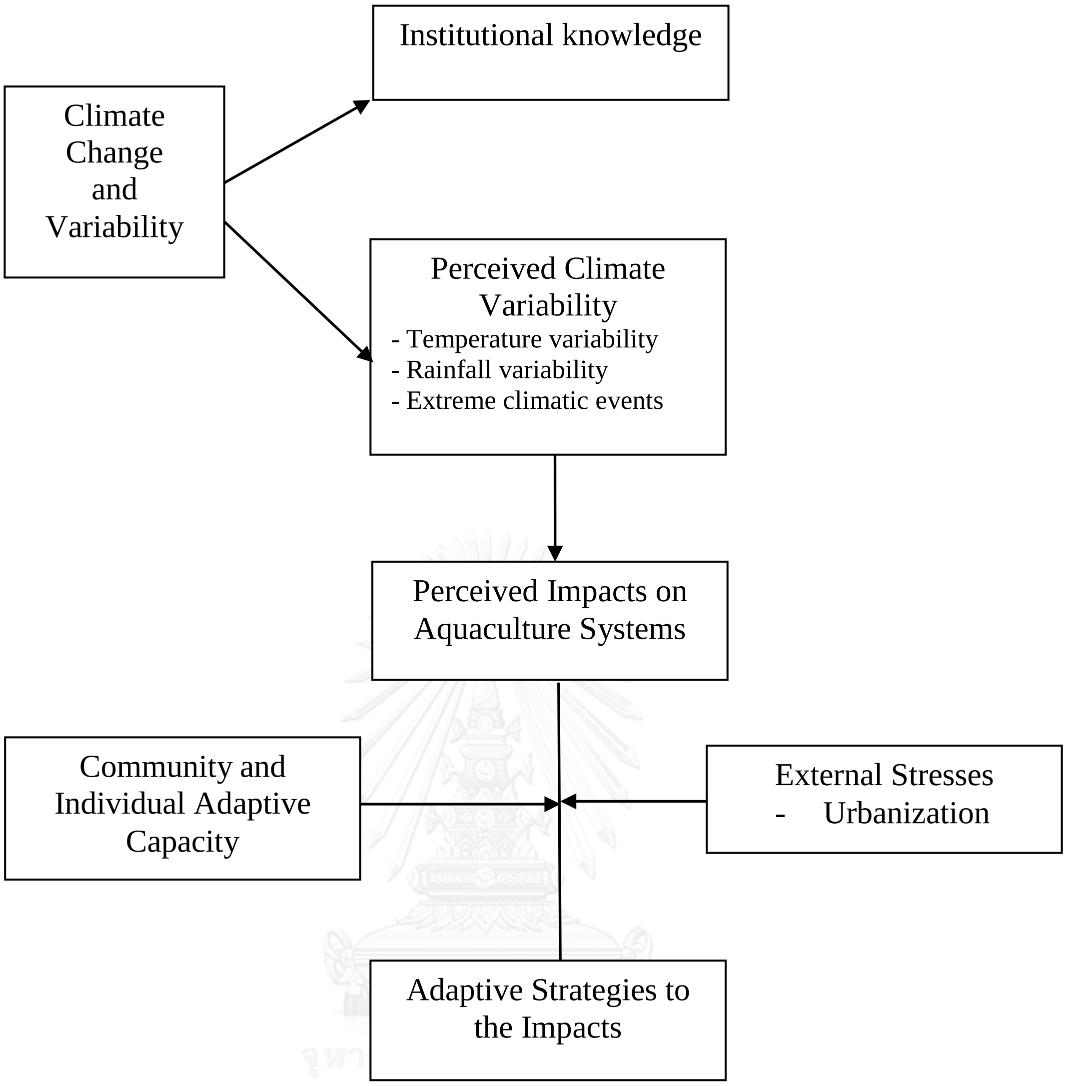


Figure 1: Illustrated Conceptual framework

1.6. Research Methodology

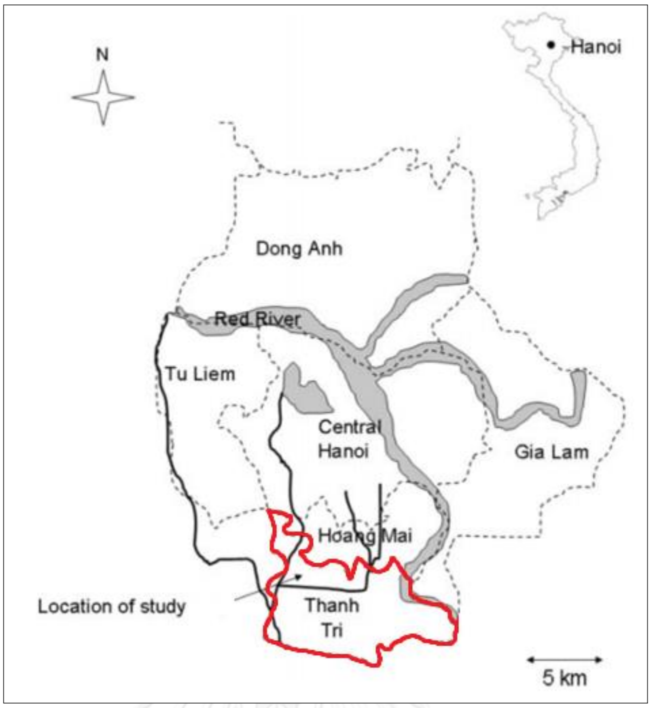
1.6.1. Scope of Research

The research focuses on fish farming and chooses Thanh Tri District as a case study because some relevant criteria (Figure 2). First, Thanh Tri as an example of peri-urban areas in which rural district is changed by urban functions such as housing, industry and infrastructure for the needs of the expansion of Hanoi City, which is quite typical of rural–urban fringe areas anywhere in the world (van den Berg et al., 2003). Second, peri-urban Hanoi fish production activities are concentrated in Thanh

Tri district which accounts for 52% of total productivity (Anh et al., 2007; Hop et al., 2007). The number of people engaged in fish farming in this district is around 400 farmers of total 30,000 households (van den Berg et al., 2003). Water sources of those farmers are rivers, lakes or ponds which receive wastewater from sewage network including urban and industrial wastewater and storm water (in rainy season). Thanh Tri District lies downstream of To Lich river system consisting of the four rivers Kim Nguu, Set, Lu and To Lich where receives mostly wastewater from Hanoi(Q. T. Nguyen, 2001). On one hand, because of its terrain characteristics as low lying area, the district prone to climatic risks such as floods or heavy rain. On the other hand, in the context of urbanization, it is increasingly concerned about the pollution of wastewater which will create possible risks to farmers and their families engaged in aquaculture production (Anh et al., 2007). These factors could affect significantly to the aquaculture activities as well as fish farmers in the district. More importantly, in the district, fish culture is important in sustaining the livelihoods of the commune's residents (Anh et al., 2007). Hence, the research site will give a good example of peri-urban aquaculture areas where farmers were being at risk of changes in climate and decrease water quality and the livelihood strategies they use to cope with those problems.

Specifically, the research will do fieldwork research on two communes within the district including Dong My and Tu Hiep communes which are two largest areas of aquaculture production in the district with various types of fish culture systems and scales of farming areas. Furthermore, in these two communes, there are representatives of all four fish culture systems in the district including (i) fish only system; (ii) integrated system; (iii) rice-cum-fish system; and (iv) fish seed or fingerlings system. The details of those culture systems would be explained in the chapter three on study area. More notably, the main difference between two communes is that Dong My commune belongs to aquaculture zone of the Hanoi City's planning and Tu Hiep commune belongs to city's urban planning which likely replace aquaculture land to urban land by 2020. This particular difference between two communes leads to the difference in resource constraints to farmers and affect to farmer's adaptive capacity.

Figure 2: Location of Study Area



Source: T. D. P. Nguyen and Pham (2005)

1.6.2. Data Collection

Qualitative method was used as a key methodology in the study to collect primary data. The study used various research tools such as semi-structured interviews and in-depth interviews using questionnaire with farmers; and key informants with district governmental organizations.

1.6.2.1. Primary Data Collection

Sampling Procedure

On one hand, the study focused on conducting semi-structured interviews with farmers as key data collection instruments during the field research. The fieldwork was implemented from May to June, 2015 in two communes of Dong My and Tu Hiep. Regards to sampling choosing, the study purposely selected sixteen farmers with different type of fish culture systems and farm scales and who are available during the fieldwork to ensure the best possible samples in terms of culture systems and scales (Table 1). In details, all eight small-scale farms with the areas smaller or equal 2.1 hectares[1] (ha) locate in Dong My communes. Besides, there are four medium-scale farms whose areas greater than 2.1 ha and smaller than 10 ha, in which two farms locate in Dong My commune and two in Tu Hiep commune. The rest of chosen farms have large-scale areas equal or greater than 10 ha and all locate in Tu Hiep commune.

The reason of choosing samples based on fish culture systems and scales is because the research would investigate whether farmers practicing different systems perceive climate variability in different ways and how their perceptions influence the way they adapt to climate variability. Due to the constraint of selecting only small groups of people, the study may not be representative of aquaculture population in the area as a whole. The aims of the study was to obtain the in-depth and detailed analysis of phenomena of growing concern regarding climate change, rather than draw general conclusion about it.

Table 1: Chosen sampling in terms of different culture systems and farm scales

	Fish only system	Integrated system	Rice-cum-fish system	Fish seed/ Fingerlings system	**Total**
Small-scale farm (smaller or equal 2.1 ha)	2	2	0	4	**8**
Medium-scale farm (greater than 2.1 ha and smaller than 10 ha)	1	1	1	1	**4**
Large-scale farm (larger than 10 ha)	3	0	1	0	**4**
Total	**6**	**3**	**2**	**5**	**16**

[1] 1 hectare (ha) = 10,000m2

Semi-structured and In-depth Interviews

In term of interviews, the author developed a questionnaire in local language for farmers with combination of close-ended and open-ended question based on four main parts. The first part of questionnaire contains basic information of farmers including age, gender, number of family members, etc. and their aquaculture production including the total size of farm, production system, number of years of farming experience, productivity, income from aquaculture, etc. The second part aims to get information about farmers' perspectives about climate changes; its causes and impacts on their aquaculture production. The third part explores their coping strategies in short-term and adaptive strategies in long-term to respond to the changes in their production. The last part of the questionnaire finds out the adaptive capacity of external elements which influence to those changes. For the purpose of this study, a total of sixteen farmers working in aquaculture in two communes were interviewed during the fieldwork. In each interviews, the researcher started by introducing herself, the purpose of the study and overview of interview content. The interviewer asked the questions in the questionnaires, used recorder to record the answers in order to save time and noted the other issues outside the questionnaires if needed. Depend on respondent's willingness to participate into the interview and their characteristic, some questions were cut or added for particular respondents.

Table 2: Summary of profile of households' responses

Item	Unit	Result
Number of interviewees	Person	16
Average household size	Person	3.5
Average age of interviewees	Year	50
Main income generator	Number	62.5% male 25% both female and male 12.5 female

Key Informants Interviews

On the other hand, combining with interviews with fish farmers, the study conducted key informants interviews with one aquaculture specialist working at Economic Planning Unit of Thanh Tri District People's Committee to discuss some key issues and collect related documents and data. The guiding themes for key informant include perceptions in climate variability and future risks of the changes in climate; impacts of climate variability in aquaculture in the district; policy responses to support farmers reduce impacts of climate variability; and future plan for aquaculture in the district and two communes.

1.6.2.2. Secondary Data Collection

The other method of the study was the utilization of secondary sources, such as NGOs and government reports, laws and policies. On one hand, the study collected the published texts, reports and statistics about climate changes in Vietnam as well as extreme climatic events in Hanoi. On the other hand, the study use the official statistics from local government as well as other organizations' reports about Thanh Tri district such as climate record, population, number of households, land use change, type of agriculture and aquaculture, fish production etc. to have overview about the context as well as analyze the changes within aquaculture production in the district under the context of climate variability. Besides, the thesis will use literature review or previous papers on peri-urban aquaculture in Thanh Tri District to have information of the aquaculture activities as well as other production in the district.

1.7. Data Analysis

After collecting data from the interviewees and key informants, the researcher applied the data treatment and analysis with transcribing, translating, coding and analysis. After the field work, the research transcribed all recorded interviews into Microsoft Word and Excel, then translated from local language to English. In next step, coding was used to organize data according to key issues such as perceptions on climate variability, impacts of climate variability, adaptive strategies, and barriers to adaptation which easily to find and prepare for analysis steps. The findings were analyzed descriptively case by case to answer each research question. During the analysis process, the answers were compared to find the similarity and patterns to support for the study's argument as well as to check the validity of the information by cross-checking.

1.8. Research Constraints and Limitations

In terms of difficulty in doing research, because the climate information and report of the district is often generalized, it was hard to collect the data about the specific climatic factors and the trends of climate in the period of 30 years in the district. Because of its close distance to urban center of Hanoi (10-15km) and difficulty to access to climate data of the district, the study assumes that the climate in Thanh Tri District has the same pattern to Hanoi. Thus, for the estimated trends in average, maximum, minimum temperature and rainfall in the period of 40 years from 1971 to 2010, the study utilize the results of D.-Q. Nguyen, Renwick, and McGregor (2014)characterizes rainfall and temperature variability for the whole of Vietnam and for climate eight sub-regions in which Hanoi belongs to N3 region.

Regards to the limitation of the study, the research strategy of case study chosen to explore the research problem in this study refers to individuals and households, and therefore may not be representative of the population in this region as a whole. In addition, the data collected was predominantly qualitative, which relies on descriptive information of the past events. Thus, some respondents may answer interview questions incorrectly simply because they have a poor memory, while others may not even speak the truth. In other words, information provided by respondents might contain several potential sources of bias such as selective memory, telescoping, attribution, and exaggeration. The researcher has to take what people say at face value. Data triangulation involves the use of different data collection methods including observations, and individual interviews, which will hopefully compensate for these limitations, as well as exploit their respective potential and advantages.

1.9. Significance of the Research

Due to the significance of aquaculture in peri-urban Hanoi is not only boundary in contributing food supply for growing urban population, providing income and livelihoods for low-incomes, but also greening the city, it is necessary to understand how the aquaculture production and systems in peri-urban are vulnerable to climate variability. Further, by exploring link between fish farmers' perceptions on climate variability and their adaptive strategies as well as adaptation barriers, it is expected to support for local policy makers to understand the farmer's perspective on climate change and its impacts as well as the local knowledge in responding to those changes; in turn, the study aims to provide recommendation for policy makers to initiate support programs for aquaculture development in the area. Moreover, because of the growing attention given to urban aquaculture, especially in Asia, the research results would share the local knowledge to other area with same characteristics in aquaculture systems.

CHAPTER II
LITERATURE REVIEW

Second chapter of the research reviews the key concepts and approaches which are used to investigate and discuss farmers' perceptions of climate variability, impacts on aquaculture systems and adaptation in Thanh Tri District. The first section of the chapter clarifies definitions related to climate change and variability and illustrates the overview of climate change in Vietnam and drivers of those changes. The second part defines climate change impacts and impacts assessment approaches. In addition, the impacts of climate change on aquaculture in general and in Vietnam particular are reviewed. The third part of the chapter focuses on adaptation to climate change and variability with key concepts and approaches as well as overview of adaptive strategies in aquaculture. Based on the literature review, the chapter points out the knowledge gap in the field.

2.1. Climate Change and Variability

2.1.1. Definitions

Weather vs. Climate

"Climate is what you expect, weather is what you get" – Heinlein, 1974

Weather illustrates the atmospheric conditions at a particular place and time measured in terms of variables including temperature, humidity, air pressure, wind speed and precipitation (USAID, 2007; USGCRP, 2009). The weather averaged during a period of time, typically 30 years, is called climate (MONRE, 2008). According to the Intergovernmental Panel on Climate Change (IPCC), "climate is usually defined as the "average weather", or more rigorously, as the statistical description of the weather in terms of the mean and variability of relevant quantities over periods of several decades" (IPCC, 1997).

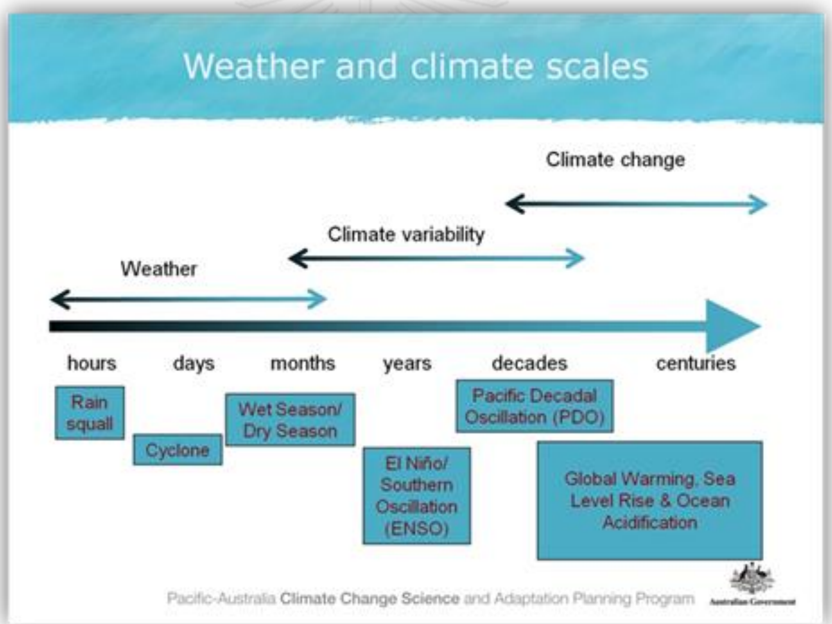
Climate Variability vs. Climate Change

Climate variability is natural changes in climatic system and occurs as a year-to-year fluctuation and a normal range of extreme conditions (ISDR, 2008; USGCRP, 2009). Climate variability can be understood as two main and complementing parts including average and range (MSG, 2011). First, climate variability is the fluctuation from year to year around the normal (often understood as 30-year average weather) at a particular place, as measured by temperature and precipitation. Second, climate variability refers to the range of weather or the variety around the averages, especially the frequency and magnitude of extremes such as heavy downpours, cold snaps or heat waves (ISDR, 2008; MSG, 2011). Common drivers of climate variability are climate patterns such as El Niño Southern Oscillation (ENSO) or La Niña and other phenomena (MSG, 2011; USGCRP, 2009).

Climate change refers to a significant and persistent change in the mean state of the climate or its variability (USGCRP, 2009) or "a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer" (Hegerl et al., 2007, p. 667). Climate change also can be understood as changes through increasing in frequency and intensity of extremes weather events including storm, flood, drought and irregular rain over time and irregular climate signal (Cruz, Harasawa, Lal, & Wus, 2007; Smit, Burton, Klein, & Street, 1999). IPCC defined climate change as "any change in climate over time whether due to natural variability or as a result of human activity" (IPCC, 2007, p. 871). Thus, climate change is not only the natural phenomenon but is also accelerated by human activities (O'Brien, O'Keefe, Rose, & Wisner, 2006), which can be the resulting changes of internal processes or external forces (Nicholls, 2007). Unlikely IPCC, according to United Nations Framework Convention on Climate Change (UNFCCC), climate change refers to "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 periods' (UN, 1992, p. 3).

Overall, in order to simplify the difference between weather, climate variability and climate change, it is practical to perceive how they operate on different time scales (Figure 3). Specifically, while weather refers to short-term (hourly, daily or maybe monthly) state of the atmosphere (Fox & Seielstad, 1998); climate refers to months, years and decades; and climate change refers to decades and centuries (PCCSAP, 2014). Examples of weather are rain storms may lasting for hours or tropical cyclones lasting for days, climate variability refers to the fluctuation of average annual temperature over seasons or years and climate change mentions to things happening over centuries such as global warming or sea level rise.

Figure 3: Different timescales applicable to weather, climate variability and climate change



Source: PCCSAP (2014)

2.1.2. Climate Change in Vietnam

Climate Change Situation and Challenges in Vietnam

Vietnam's climate is characterized by the interplay of the East Asian and South Asian Monsoons, cold surges in the winter months and a long rainy season which extends beyond summer. Vietnam is predicted as one of the most vulnerable countries to climate change likely to face significant impacts from it, particularly in concentrated population ‘mega-deltas’ such as the Mekong and Red River Deltas (IFAD, 2014). In the 4th assessment of IPCC, Vietnam is characterized as a “hotspot of key future climate impacts and vulnerabilities in Asia” (Cruz, Harasawa, Lal, Wu, et al., 2007).

According to observed statistic data, Vietnam has experienced changes of climate parameters and sea level with noticeable increases in average annual temperatures, especially likely urban heat island effects in cities and urban areas; variability of both rainfall and temperature between years and within seasons; and a likely increased occurrence of higher intensity storms (IFAD, 2014; MONRE, 2009).

In term of temperature variability, during 50 years from 1958 to 2007, the annual average temperature in the country increased about 0.5 to 0.7◦C (MONRE, 2009) which is not far from the global average. Furthermore, winter temperature escalated faster than that in summer (MONRE, 2009; D.-Q. Nguyen et al., 2014) and temperatures in Northern climate zones increased faster than those of Southern climate zones. The latest study about climate variability in Vietnam found the same trends in temperature variability that there was an increase in annual average temperature of 0.26±0.10◦C per decade during 4 decades from 1971 to 2010, which is approximately double the rate of global warming over the same period (D.-Q. Nguyen et al., 2014). Winter temperatures are greater than those of summer by about 25-40%. Particularly, in cities and urban areas, it is recorded that annual average temperature for 1991 to 2000 in Hanoi (the North), Da Nang (the Central) and Ho Chi Minh City (the South) were all higher than the average for 1931-1940 by 0.8; 0.4 and 0.6◦C respectively (MONRE, 2009). In 2007, the annual average temperatures at these three locations were all higher than the average for 1931-1940 by 0.8-1.3◦C (MONRE, 2008). It is also proved that there is existence of urban heat island effects (UHI) in large cities in the country. For example, in 2010, the air temperature difference in Hanoi reached 2◦C, which show the subsistence of UHI in Hanoi (Tran et al., 2015).

Regards to precipitation variability, it was documented that dominant trends for annual rainfall over the whole country are declined (D.-Q. Nguyen et al., 2014).

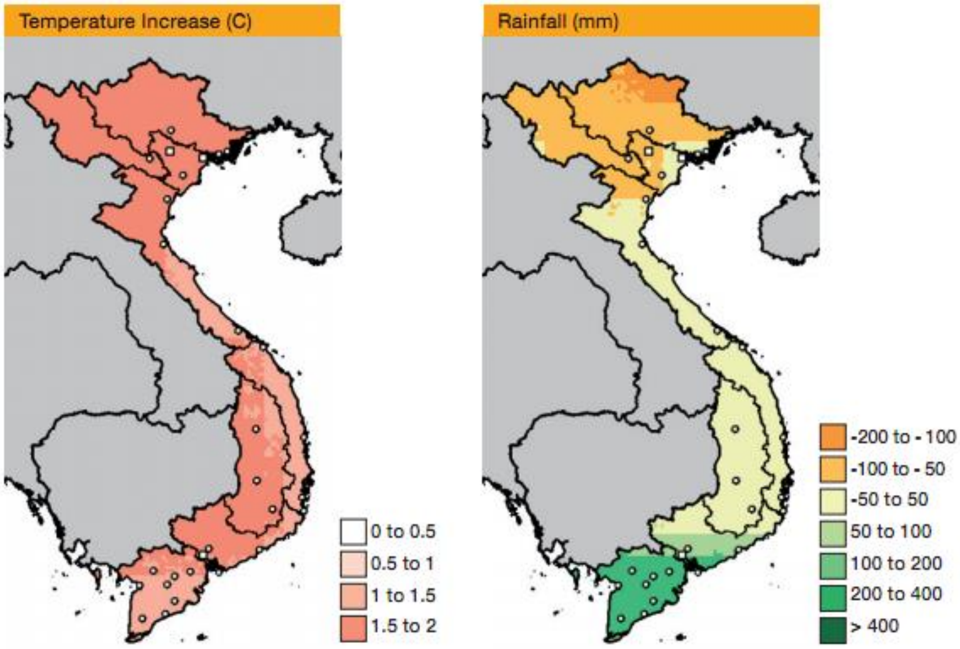
The annual average rainfall over 50 years from 1958 to 2007 descended by approximate 2% (MONRE, 2008), however, the change was not consistent with different rate for distinct regions (MONRE, 2009). While the annual rainfall decreased over Northern climate zones, it increased over Southern ones. Data from 1931 to 2000 also showed that the precipitation has an increasing trend in Da Nang, and reversely a decreasing trend in Hanoi and Ho Chi Minh City (V. T. Nguyen, Nguyen, & Tran, 2008).

Related to sea level, statistic data in a period of 50 years from 1958 to 2007 illustrate that sea level has been rising much more compared to global averages, from 25 to 30 cm (MONRE, 2009).

Projected Climate Change in Vietnam

Climate change scenarios for the country suggest that impacts are likely to derive primarily from rising sea levels and changes in rainfall and temperatures (IFAD, 2014; MONRE, 2008, 2009). According to Vietnam's official climate change scenario, the annual average temperature in all regions would escalate by 2◦C in 2050 and is projected to ascend by 3◦C in 2100 (MONRE, 2009). The latest MONRE report conducted in 2012 gives scenarios further insight into the wider range of predictions in climatic variability for Viet Nam (ADB, 2013). The report illustrates the average temperature would increases from 1.9°C–3.1°C over large parts of the country with most extreme increases in the Central Region of more than 3.1°C. More significantly, number of days with temperatures above 35°C is predicted to increase by 10–20 days in large parts of the country. Over the same scenario, the average rainfall will increase by 5.8% (MONRE, 2009), but the precipitation would change in different regions. It may ascend 0-10% in rainy season and descend 0-5% in dry season and the fluctuation would occur more. The sea level is estimated to rise about 100cm in 2100 (MONRE, 2009). The report also forecasts that extreme climatic events such as typhoons and cold surges are expected to occur more frequently with higher intensity in the future. Figures 4 demonstrates the predicted changes in the climate change scenario based on the country's Second National Communication to the UNFCCC (MONRE, 2010).

Figure 4: Predicted changes in temperature and rainfall – 2050



Source: IFPRI (2011)

2.1.3. Drivers of Climate Change in Vietnam

Urbanization and industrialization are considered to be attributing to global climate change (IPCC, 1990; Srinivasan, Krishna, & Goswami, 2007). Urban growth and industrial activity have great impacts on local environments with various physical occurrence that can result in local environmental stresses (Revi et al., 2014). These include urban heat islands (UHI) effect which urban areas have higher temperatures, particularly at night, than surrounding rural locations and local flooding that can be worsen by climate change. Number of previous studies across cities around the world found out that there is correlation between the intensity of urbanization and long-term trends in surface air temperature in urban areas (Chen, Li, Niu, & Sun, 2011; Fujibe, 2008, 2011; He, Liu, Zhuang, Zhang, & Liu, 2007; Iqbal & Quamar, 2011; Jung, 2008; Kalnay, Cai, Li, & Tobin, 2006; Kolokotroni, Davies, Croxford, Bhuiyan, & Mavrogianni, 2010; Ren, Chu, Chen, & Ren, 2007; Rim, 2009; Sajjad et al., 2009; Santos & Leite, 2009; Stone, 2007; Tayanç, İm, Doğruel, & Karaca, 2009) quoted in (Revi et al., 2014). Further, the hot climate of cities causes changes in sensible het fluxes and the concentration of atmospheric pollutants (Barnes, Morgan, & Roberge, 2001). The natural density of many large cities influence prominently on anthropogenic heat fluxes and surface roughness (Revi et al., 2014). It is explored that the anthropogenic heat emissions over small areas of large cities can be triple or four times higher the average values across those cities (Allen, Lindberg, & Grimmond, 2011; Flanner, 2009). In addition, the massive spatial extent and significant amount of built-up areas of megacities with population of 10 million or more can have considerable impacts on related environmental qualities such as air quality (Bohnenstengel, Evans, Clark, & Belcher, 2011). More notable, megacity-coastal interactions can impact the hydrological cycle and pollutant removal processes through the development of fog, clouds, and precipitation in cities (Ohashi & Kida, 2002; Shepherd et al., 2011). Urbanization and industrialization are also two main factors contribute to changes in climate in Vietnam.

Drivers of Climate Change in Vietnam

- Industrialization

Climate change concerns have risen recently since Vietnam has witnessed a very rapid GDP growth, averaging 6 to 8% over the last decade (Van Dijk et al., 2013). Industrialization has significantly contributed to the country's economic growth by intensive exploitation of natural resource, resulting in an escalation in energy consumption and corresponding exponential increase in greenhouse gas (GHG) emissions (ADB, 2013). In 2008, national energy consumption increased by 11.3%, a consistent trend over the past decade (APERC, 2011). Due to the growth trend in total energy use and the heavy dominance of fossil fuels, total national emissions were reported to equal 151 million tons and 177 million tons of GHG in carbon dioxide equivalent (CO2e) in 2000 (MONRE, 2010) and 2005 (ADB, 2013) respectively, which are projected to triple by 2030 (WB, 2011).

- *Urbanization*

Furthermore, Viet Nam is undergoing one of the fastest urban transitions in the world, which is the main driving force for economic growth. According to the latest data from World Bank, Vietnam has 33% of total population of more than 90 million people living in urban areas (WB, 2014). In which, the four biggest cities including HCMC, Hanoi, Da Nang, Hai Phong already take account of almost 12 million people representing 44% of the whole urban population. Of these cities, though HCMC is the biggest city with more than 6 million people, Hanoi – the capital has experienced the fastest growth at a pace of more than 4% per year (UNDESA, 2012).

The urban population in the country is forecasted to increase to 45% (equal to 46 million people) by 2020 and to 50% by 2030 (ADB, 2013) due to the rapid move of migrants from rural areas to urban centers and people leaving agriculture for industry and services (WB, 2011). The rapid growth of industry and urban expansion which impinge the rural land results in changes associated to natural resource especially land use; weather, climate; and related local environmental quality.

Effects of Industrialization and Urbanization

- Changes in Land Use

In terms of land use changes, the rapid industrialization and urbanization reflects in the gradually increase of build-up areas by 54% from 16,091 km2 in 2000 to 26,551 km2 in 2010 (Table 3). The data also illustrates the ascending of agricultural land from 29% to 31%, mainly increase in perennial crop land but reduction in paddy rice land. Land use change is particularly significant in forest land. Intense exploitation and conversion resulted in the decrease of forest cover from 43% in 1943 to about 27% in 1990 (ADB, 2013). This then escalated by 33% from 2000 to 2010. However, this improvement has been found due to increases in plantation forest and poor quality secondary forest (MARD, 2007). Growth in agricultural land and production forest land has been at the expense of unused land which reduced by 65% from over 82 in 2000 to nearly 30,000 km2 in 2010. This implies that there is limited capacity to expand agricultural and built-up land in Vietnam and the pressure to agricultural intensification becomes significant. High intensive land use is achieved through the widespread application of agriculture inputs such as fertilizers and pesticide. Worse, land utilization becomes more intensive with the conversion of marginal lands previously unsuitable for agriculture, which consequently leads to deforestation, greater levels of soil erosion, lower level of productivity, and groundwater and surface water contamination (ADB, 2013).

Table 3: Land use data, 2000-2010

	Km2		**%**		**%**
	2000	**2010**	**2000**	**2010**	**2000-2010**
Agricultural land	95,700	101,522	29	31	6
Forest land	115,754	153,665	35	46	33
Built-up land	16,091	26,551	5	8	54
Land with rivers, canals and streams*	21,493	20,831	7	6	-3
Unused land	82,174	28,744	25	9	-65
Total land	331,212	330,957	100	100	0

* Includes land for aquatic farming

Source: MARD (2007)

- Changes in Urban Climate

Further, recent studies on urban climate identified urban heat island effects (UHI) in some large cities in Vietnam by showing the relationship between various land uses and urban surface temperature. For instance, the results in a study using thermal remote sensing methodology showed that in HCMC, while industrial areas have highest surface temperature (35-39◦C) followed by built-up areas, areas covered with vegetation were evaluated to have lower surface temperature (24-28◦C) (Van & Bao, 2006). The UHI in HCMC was verified again in another research using data from 1989 to 2006. It is demonstrated that the built-up areas in the city expanded by 6.5 times during the period with the highest land surface temperature of greater than 45◦C in industrial areas and within 36◦C and 40◦C in urban areas (Van & Bao, 2009). In Hanoi – the second largest city, a preliminary UHI study was conducted in 2012 to estimate the UHI effect due to land use change proposed by the Hanoi Master Plan (Phuong, 2012) followed by the study of Trihamdani et al. (2014). The results show that the peak air temperature in the urban areas in the master plan condition was predicted to maintain almost the same level as the current condition of 41°C (up to 1°C higher). However, high air temperature areas would expand widely in the planned built-up areas. Simulated nocturnal air temperature increased by up to 3-4°C over the expanded built-up areas. The wind speed in expanded built-up areas was also weaker than those over green spaces (Trihamdani et al., 2014)

➢ Changes in Local Environmental Quality

In addition to influence on urban surface temperature, urban growth and industry activity also leads to the increase levels of land, water and air pollution. Water quality in the country is seriously affected with increasing concentration, toxicity and variety of pollutants from untreated domestic, hospital and industrial wastewater, poor urban drainage and sewage, and an extension in using rivers, lakes or ponds as dumping grounds for solid waste (ICEM, 2007a, 2007b). Moreover, air pollution is also exacerbating with about 667,000 tons of sulfur oxides, 618,000 tons of nitrogen oxides, and 6.8 million tons of carbon monoxide generated annually (MONRE, 2011). A recent study conducted in 2010 about air quality in Asian cities ranks the air quality problems in Hanoi are worse than that in Bangkok but better than those in Jakarta and Manila (CAI, 2010).

2.2. Climate Change Impacts:

2.2.1. Assessing Approaches of Impacts of Climate Change

According to IPCC (2007, p. 875), climate change impact assessment is defined as “the practice of identifying and evaluating the effects of climate change on natural and human systems”. Those effects might be positive or negative depending on the context. Moreover, climate change impacts are often evaluated in accordance with current assessment of adaptation options and exploration of future possible adaptation strategies for response to a changing climate. Empirical studies pointed out three well-known methodological approaches for assessing climate change impacts and adaptation strategies including impact, interaction and integrated approach (Carter, Parry, Harasawa, & Nishioka, 1994).

Impact Approach

First and the foremost, the simplest methodology is called impact approach or "If - Then - What" approach. Its simplicity lies in the straightforward "cause and effect" pathway. The question needed to be answered is that if the climate change happens then what its impacts would be. Based on the assumption that the effects of non-climatic factors on the exposure unit can be invariable, the impact approach is usually adopted for studies of individual activities and hierarchy of level studies. The clear limitation of the approach is that the approach only focuses on the effects of climate change depend on climatic factors, not non-climatic ones.

Interaction Approach

Second, in order to closer the gap of the first approach, interaction approach was applied with the recognition that climate factor is only one of a set of factors that affect or is affected by the exposure unit. In other words, exposure unit is not only influenced by climate factors but also by other factors such as the environment and non-environment. However, exposure unit may influence the climate factors and non-climate factors through its activities. Thus, the approach can be considered as a "What-Then-If" approach. The question needed to be addressed is that what issues in a system are sensitive to climate change and then what fields will be impacted if climate change happens. The difference between this approach and the first approach in that if the former considers non-climate factors to be steady, the latter regards non-climate factors may have impact on the exposure unit. Moreover, the latter approach selects climate factors based on climate-sensitivity of the exposure unit. Though, both approaches have their limitations, so the integrated approach is mentioned to reduce the gap of the above approaches.

Integrated Approach

Last but not least, the integrated approach is the most comprehensive in terms of the interactions between society and climate factors. This approach seeks interaction within sectors, between sectors and feedbacks. Further, it also refers to adaptation strategies to diminish impacts climate change. While basic knowledge is inadequate to envisage conducting a fully integrated assessment, it is needed to combine with different sectors in the same region. Hence, this approach has become popular in many studies of scientists associated with climate change. Since a key limitation of most impact assessment to climate change is the insufficiency and lack of in-depth adaptation strategies, this approach refers that adaptation strategies to climate change including modification in the systems cannot be separated from the impact assessment of climate change.

Furthermore, the ascending pressures related to human activities such as over population, poverty, natural resource degradation, environmental pollution exacerbate the climate change impacts (R.J.T. Klein, 2002; Nicholls et al., 2007). Particularly, the impacts of climate change in the developing countries are caused by not only climate factors but also non-climate factors such as socio-economic issues (Schipper, 2004). In this research, the interaction approach is used to discover the perceived impacts of climate variability and causes of those changes with both climate factors and non-climate factors.

2.2.2. Impacts of Climate Change on Aquaculture

Different geographical regions, sectors, systems or individuals are impacted unequally by climate changes. In order to reach the research objectives, the literature review only focuses on the impacts of climate change on aquaculture. Because the natural and human processes in aquaculture are different from mainstream agriculture, it is particularly vulnerable to impacts and interactions related to climate change (Porter et al., 2014). Moreover, impacts of climate change on aquaculture could occur directly and or indirectly and not all features of climate change will impact on aquaculture (Daw et al., 2009). In aquaculture, integrated assessment approach was used to analyze the potential direct and indirect impacts of climate change on aquaculture systems and production which is based on climate scenarios (De Silva & Soto, 2009; Handisyde, Ross, Badjeck, & Allison, 2006). These assessments are based on the basic structure of the present aquaculture system and the path of climate change impacts on the system. Climate change will affect aquaculture through gradual warming, ocean acidification, changes in the frequency, intensity, and location of climate patterns and extreme events, and changes in precipitation with associated changes in groundwater and river flows (IPCC, 2014, FAO 2009a).

The most comprehensive study about to aquaculture and climate change suggests the influence of predicted climate changes such as temperature, precipitation, sea level rise, extreme events, climate variability and ocean currents on global aquaculture (Handisyde et al., 2006). Table 4 shows the potential impacts of climate change on aquaculture production and systems.

Table 4: Impacts of climate change on aquaculture systems and production

Drivers of Change	Impacts on culture systems	Operational Impacts
Sea surface temperature changes	• Increase in harmful algal blooms that release toxins in the water and produce fish kills • Decreased dissolved oxygen • Increased incidents of disease and parasites • Enhanced growing seasons • Change in the location and/ or size of the suitable range for a given species • Lower natural winter mortality • Enhanced growth rates and feed conversions (metabolic rate) • Enhanced primary productivity to benefit production of filter-feeders • Altered local ecosystems – competitors and predators • Competition, parasitism and predation from exotic and invasive species	• Changes in infrastructure and operation costs • Increased infestation of fouling organisms, pests, nuisance species and/or predators • Expanded geographic distribution and range of aquatic species for culture Changes in production levels
Increase in frequency and/or intensity of storms	• Large waves • Storm surges • Flooding from intense precipitation • Structural damage	• Loss of stock • Damage to facilities • Higher capital costs, need to design cages moorings, jetties etc. that can

	• Salinity changes • Introduction of disease or predators during flood episodes	withstand events • Negative effect on pond walls and defenses • Increased insurance costs
Higher inland water temperatures (possible causes: changes in air temperature, intensity of solar radiation and wind speed)	• Reduced water quality especially in terms of dissolved oxygen • Increased incidents of disease and parasites • Enhanced primary productivity may benefit production • Change in the location and/or size of the suitable range for a given species • Increased metabolic rate leading to increased feeding rate, improved food conversion ratio and growth provided water quality and dissolved oxygen levels are adequate otherwise feeding and growth performance may be reduced	• Changes in level of production • Changes in operating costs • Increase in capital costs e.g. aeration, deeper ponds • Change of culture species
Floods due to changes in precipitation (intensity, frequency, seasonality, variability)	• Salinity changes • Introduction of disease or predators • Structural damage • Escape of stock	• Loss of stock • Damage to facilities • Higher capital costs involved in engineering flood resistance • Higher insurance costs
Drought (as an extreme event (shock), as opposed to a gradual reduction in water availability)	• Salinity changes • Reduced water quality • Limited water volume	• Loss of stock • Loss of opportunity – limited production (probably hard to insure against)
Water stress (as a gradual reduction in water	• Decrease water quality leading to increased diseases • Reduce pond levels • Altered and reduced freshwater supplies	• Cost of maintaining pond levels artificially • Conflict with other water user

availability (trend) due to increasing evaporation rates and decreasing rainfall)	– greater risk of impact by drought if operating close to the limit in terms of water supply	• Loss of stock • Reduced production capacity • Increased per unit production costs • Change of culture species

Source: modified from Handisyde et al. (2006)

Particularly, in fresh water aquaculture, Ficke, Myrick and Hansen (2007) suggested that the general effects of climate change on fresh water systems will occur through increased water temperature, decreased oxygen levels and the increased toxicity of pollutants. First, warmer temperatures increase metabolic rates, but if food supply is good, stocks in southern areas probably are able to overcome this increased metabolism both growth rates and recruitment may increase. Second, Ficke et al. (2007) also proposed that climatic changes could worsen eutrophication and produce more prominent stratification in lentic systems. Increased eutrophication could result in oxygen depletion in the dawn hours; sudden changes in wind patterns and rainfall could result in upwelling bringing deep/bottom oxygen depleted waters to the surface, with adverse effects on cultured stocks and naturally recruited fish stocks in the water body. Last, an increased uptake of toxicants and heavy metals through accelerated metabolic rates from increased temperature by cultured, filter feeding mollusks is suggested to be reasonable (Ficke et al., 2007). Consequently, this leads to food safety and certification issues.

2.2.3. Impacts of Climate Change in Aquaculture in Vietnam

Viet Nam has a coastline of 3,260 km with abundant natural resources contributes an important part to develop the fishery. Therefore, fishery plays an important role in the country’s economy. It contributed 6.6% in GDP in 2008 while the overall agriculture took up 21% of GDP in the same year. Moreover, export values of this sector are increasing every year and account for a big share of the total export values of the whole economy. In addition, this sector attracts a large number of workers in the whole country especially rural coastal areas. Hence, the importance of this industry is perceived clearly and any changes in this sector lead to effects on many facets of the economy, the society. Referring the structure of fishery industry in Vietnam, the fisheries sector in Vietnam can be divided in three main sub-sectors: the marine, the inland and the aquaculture sub-sector. The recreational fisheries sector is still not developed except from the production of ornamental fish. Marine fisheries are the biggest contributor to the fisheries production, followed by aquaculture.

Aquaculture is currently estimated to employ some 2.8 million people in Vietnam and have an export value (2010) of about US$2.8 billion (IFAD, 2014). Table 6 shows that Vietnam is ranked as one of top 5 countries having the highest farmed food fish production with the total productivity of about 2.2 million tons, taking account of 4.6% world share (FAO, 2014). Further, in Vietnam, aquaculture is the fastest growing form of animal husbandry(MONRE, 2010). In addition to increasing exports, the country has a growing domestic resource base and imports only limited, albeit growing, volumes of raw material. Its rising exports are linked to its flourishing aquaculture industry, in particular to the production of Pangasius and of both marine and freshwater shrimps and prawns (FAO, 2014).

Due to the important role of aquaculture in food contribution and export values and its significantly dependence on climate, it is essential to consider the influences of climate changes on aquaculture in the country. MONRE (2010) addressed climatic factors could possible impacts on aquaculture including rising temperature, floods and storms, sea level rise or salinization in coastal areas.

Similar to the studies on climate changes impacts on global aquaculture, it has been found that increasing temperature may have an effect on the metabolism, growth and seasonal reproduction of aquatic organisms and make them more vulnerable to diseases and toxins (MONRE, 2010). Dissolved oxygen in water may fall down quickly at night, impeding the growth and killing fishes and shrimps. Furthermore, rising temperature enhance the growth and development of harmful micro-organisms at the expense of fish stock. For instance, red tides phenomenon in which the rapid over-blooming and accumulation of red, blue, green and brown micro-algae due to rising temperatures consequently decrease dissolved oxygen and leads to the mortality of fishes and invertebrates (MONRE, 2010).

Besides, floods and storms can damage fish ponds, fish cages; reduce estuarine water salinity and seriously affecting aquaculture production. More notably, sea-level rise will aggravate saltwater intrusions in coastal areas, which in turn will cause the loss or retreat of mangrove forests (IFAD, 2014; MONRE, 2010). The associated loss of habitats may reduce stocks of fish, mollusks and crustaceans. The intrusion of saltwater into freshwater estuaries and coastal lagoons will cause the replacement of freshwater species by their brackish and saline water counterparts. Freshwater catfish farming in particular could face an uncertain future as a result of rising prices for feedstuffs and the costs of maintaining water quality as salinization increases. Some fish species, such as catfish, may grow more rapidly with higher temperatures but be more vulnerable to disease. This leads to the high risk for catfish farming which accounts for more than 50 per cent of total aquaculture revenues (IFAD, 2014).

2.3. Adaptation to Climate Change

2.3.1. Adaptation and Adaptive Capacity

2.3.1.1. Definitions of Adaptation

Adaptation Concept

While "adapt" refers to a process of adjustment to changing circumstances. "adaptation" refers to the process of adapting and the condition of being adapted. According to Burton (1992) cited in Smit et al. (1999), adaptation in social sciences was concerned with "the process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides". Similarly, Carter et al. (1994) described that adaptation refers to any adjustment, whether passive, reactive or anticipatory that can respond to anticipated or actual consequence associated with climate change.

Coping Concept

In addition to the concept "adaptation", "coping" is also used to describe responses of human in confronting with climate change impacts. The differences between coping and adaptation are contested, although there is not literature which explicitly discusses this issue. The principal distinction between coping and adaptation is the difference in temporality and sustainability (IPCC, 2001; Smit & Wandel, 2006; Smithers & Smit, 1997). Coping occurs in the context of immediate dangers and is aimed to overcome acute damage. The purpose of coping actions is thus to survive in an adverse situation. For example, coping strategies in response to climate change impacts might be selling assets or livestock in exchange for food lost from unexpected flood or moving to a place with higher altitude. In contrast, the purpose of adaptation is to prevent or limit current and future damage of events of climate change. Adjusting seasonal calendars or building a high and permanent house to avoid annual floods is considered to be examples of adaptation to climate change. It becomes clear that coping and adapting are different ways to respond to risk that cannot be interchanged (IPCC, 2001). There is, however, also a relationship between coping and adaptation. According to Lazarus (1993), the effectiveness of coping can produce an outcome which can be considered as adaptation. Similarly, an outcome considered as maladaptation can origin from ineffective coping strategies which degrade long-term capacity to escape from poverty or cope with future extreme events (Osbahr, Twyman, Adger, & Thomas, 2008). In a continuous adaptation process, coping can be understood as the lowest level of adaptation if it shows effectiveness on the long-term.

2.3.1.2. Adaptation Approaches

The adaptation approaches have been undertaken differently based on various factors such as: social and economic endowments, ecological location, social network, institutional relationship, and access to resources (Agrawal, 2008). Each type of adaptation practice has its own characteristics. Nevertheless, there have been many efforts to categorize different adaptation strategies, in particular to be used as knowledge for the development of policy and planning.

Reactive Adaptation vs. Anticipatory Adaptation

Adaptation options are categorized based on various criteria. Firstly, depending on timing, adaptation can be either reactive or anticipatory (Füssel, 2007; R. Klein, Nicholls, & Thomalla, 2003; R.J.T. Klein & Maciver, 1999; R.J.T. Klein & Tol, 1997). Reactive adaptation appears after the occurrence of climate change impacts, while anticipatory adaptation takes place before climate change impacts occur. Although these differences seem to be clearly identifiable conceptually, in practice this distinction proves to be not clear. In the context of continuous changing system, reaction and anticipation mix together (Fankhauser, Smith, & Tol, 1999; R.J.T. Klein & Tol, 1997). For instance, concrete houses built on hills in the coastal area to prevent flood damages can be seen as both reactive and anticipatory action. They are results of reactive action if they are built to prevent only past and current flood regimes. They are results of anticipatory action if they are built in consideration of a warmer future. In reality they are probably built in consideration of past, present and future. However, in reality, anticipation and reaction are mixed and people often combine both reactive and anticipative adaptation strategies to cope with and adapt to climate extremes and climate variability.

Autonomous Adaptation vs. Planned Adaptation

Secondly, adaptation can also be categorized either as autonomous or planned (Carter et al., 1994; Füssel, 2007). Autonomous adaptation is defined as “natural or spontaneous adjustments in the face of a changing climate” (Carter et al., 1994, p. 32) without any policy plan or decision. Conversely, planned adaptation is adjustment which takes place in accordance with the intervention of the government - or any other informed decision-maker. The planned adaptation is made based on perceptions of climate change and the need to act to respond to such changes (R.J.T. Klein & Tol, 1997). This difference is clear in theory, but is still difficult to divide in practice. For example, the change in crops and management practices of the farmers is seen as autonomous adaptation from government’s perspective while as planned from farmers’ perspective (Fankhauser et al., 1999). Planned adaptation can be both reactive and anticipatory while autonomous adaptation is exclusively reactive.

Public Adaptation vs. Private Adaptation

Thirdly, depending on the concerned actors, adaptation can be categorized as public and private (Füssel, 2007; R. Klein et al., 2003; R.J.T. Klein, 2002; Smith, Burton, Klein, & Wandel, 2000). Private adaptation is undertaken by individual households while public adaptation is undertaken by governments. According to Mendelsohn (2000), private adaptation is performed for the individual's own benefit whilst public adaptation offers benefits for many. However, the distinction between private and public is also problematic. Although adaptation is undertaken by private individuals or firms, it is affected by government policies, in some cases (Smithers & Smit, 1997). Notably, autonomous and planned adaptation overlaps with private and public adaptation (R. Klein et al., 2003).

In summary, basing on many concepts of different authors, adaptation to climate change in this research is understood as adjustments by community and individual households to respond to the changing of climate over time. The overall purpose is to diminish impacts or enhance adaptive capacity of community and individual. Understanding adaptation concepts is important to make the foundation for evaluating and identifying impacts of climate change. Based on that, it supports choosing the adequate adaptation strategies in order to decrease climate changes impacts, reduce significantly vulnerability and risk for human, environment and nature in climate change context.

2.3.1.3. Adaptive Capacity

Adaptive capacity presents the potential, capacity or ability to adapt rather than adaptation practices (Brooks & Adger, 2005; Smit & Wandel, 2006). According to IPCC (2001), adaptive capacity is defined as the ability of a system to adjust to climate change which includes climate variability and extremes, to reduce potential damages, to take advantages of opportunities or to cope with the consequences. The community and individual could or could not adapt to climate change. First, it could depend on its resources including financial capital, social capital (e.g., strong institutions, transparent decision-making systems, formal and informal networks that promote collective action), human resources (e.g., labor, skills, knowledge and expertise) and natural resources (e.g., land, water, raw materials, biodiversity) (Brooks & Adger, 2005). Second, adaptive capacity depends on the ability of community and society capacity (Brooks & Adger, 2005).

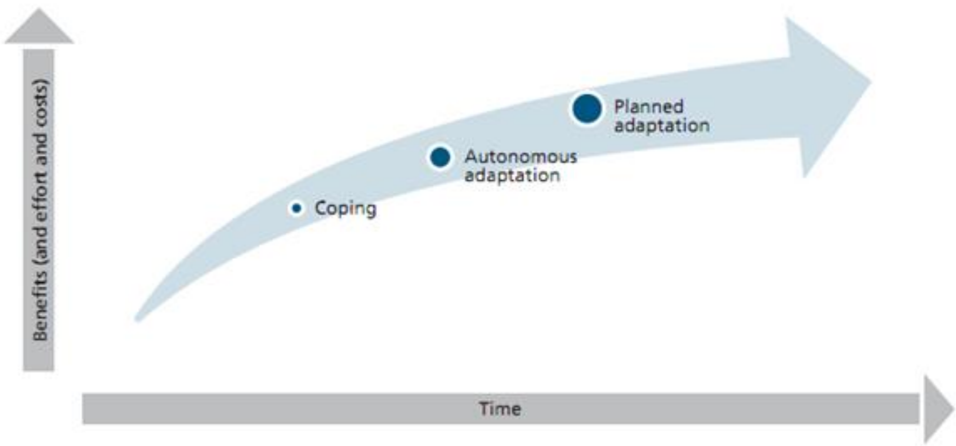
Furthermore, population pressure or scarce resource may generally reduce the capacity of community as well as of individuals and narrow its coping range, while economic development or technology or institutions improvement, financial access may lead to an increase adaptive capacity (Smit & Wandel, 2006). Moreover, communities have a strong kinship network may increase adaptive capacity though collective action and conflicts solution between its members (Brooks & Adger, 2005; Smit & Wandel, 2006). Adaptations are manifestations of adaptive capacity thus populations having better adaptations or changes in the systems can deal well with problematic exposures.

Summary, adaptive capacity implies the potential ability of community or individual in response to climate change and its impacts which depends on various resource and society capacity. This study discusses the adaptive capacity of farmers and community based on their resources or capital to examine the influence of adaptive capacity to their adaptation to climate variability and extremes.

2.3.2. Adaptive Strategies to Climate Change in Aquaculture

As mentioned above, adaptation can be planned (based on climate-induced changes) or autonomous (i.e. spontaneous reaction to environmental change). In aquaculture, adaptation can include a variety of policy and governance actions, specific technical support or community capacity building activities that address multiple sectors not just capture fisheries or aquaculture farmers. Planned adaptation may mean research funding for finding species appropriate to high-salinity environments and temperature fluctuations. Autonomous adaptation may mean changing the timing or locations of fishing as species arrive earlier/later or shift to new areas. Adaptation activities may address short- or long-term impacts (Figure 5), whereas coping is a short-term response (e.g. to storm impacts for a single season) and can undermine longer-term adaptation activities if it places addition stress on already vulnerable systems (FAO, 2014).

Figure 5: Time scale and amount of benefits and costs required for various types of adaptation



Source: FAO (2014)

Although context-specific, examples of current and recent adaptation activities for fisheries and aquaculture include those listed below:

Table 5: Examples of adaptation activities for aquaculture

Main strategies	**Detail activities**
Diverse and flexible livelihood strategies	• Introduction of fish ponds in areas susceptible to intermittent flood/drought periods, providing for direct food security as well as irrigation water storage. • Flood-friendly small-scale homestead bamboo pens with trap doors allowing seasonal floods to occur without loss of stocked fish. • Cage fish aquaculture development using plankton feed in reservoirs created by dam building. • Supporting the transition to different species, polyculture and integrated systems through technology

	transfer and access to financial resource, allowing for diversified and more resilient systems. • Promotion of rice–fish farming systems developing salt-tolerant rice varieties in the face of sea-level rise and storm surges – reducing overall water needs and providing integrated pest management. • Supporting transitions to alternative livelihoods to reduce reliance on vulnerable systems and sectors, such as business planning and professional association development.
Flexible and adaptable institutions	• Public awareness raising through appropriate media – radio, posters, etc. • Strengthened local community-driven institutions for improved fisheries management and adaptive capacities of natural and social systems, including community-level vulnerability assessments and adaptation planning • Flexible effort (e.g. vessel day) schemes to provide adaptive regional management of transboundary stocks among a group of collaborating countries. • Participatory fisheries data collection, including monitoring systems and local knowledge, increasing local knowledge and change management • Implement an ecosystem approach to aquaculture (EAA) as a global strategy • Prioritize and enhance mariculture and specially non-fed aquaculture (filter feeders, algae) • Enhance the use of suitable inland water bodies through culture-based fisheries and appropriate stock enhancement practices

Risk reduction initiatives	• Community- and ecosystem-based coastal erosion protection activities, such as the construction of perpendicular and parallel groynes, sandbars, oyster reefs, mangrove rehabilitation and replanting, restoration of wetlands and rehabilitation of coral reefs. • Improved spatial planning to identify vulnerable habitats through marine species identification, monitoring techniques and protocols to develop baseline information for planning. • Innovative weather-based insurance schemes in agriculture being tested for applicability in aquaculture. • Climate risk assessments introduced for integrated coastal zone management, supporting climate smart investment

Source: modified from Shelton (2014) and De Silva and Soto (2009)

More notably, the ecosystem approach to aquaculture (EAA) is proposed to integrate aquaculture within the broader ecosystem in order to promote sustainability of interconnected social-ecological systems (SOFIA, 2006; Soto et al., 2008). In particular, the EAA highlights the essential of integration aquaculture with other sectors such as agriculture, fisheries, urban development, etc. which share and affect simultaneously common resources (land, water, feeds, etc.). Further, the approach also emphasizes on different spatial scales including the farm; the aquaculture zone, water-body or watershed where the activity operates; and the global scale (Soto et al., 2008). It is considered that the EAA implementation at the watershed scale is one of the most relevant adaptations to climate change.

2.3.3. Adaptive Strategies to Climate Change in Aquaculture in Vietnam

The official research of MONRE (2010) in the country suggests some adaptation measures in aquaculture in short-term such as (i) designing aquaculture plans for different ecological zones on the basis of the assessments of climate change impacts on aquaculture and marine resources; (ii) developing plans to preserve marine biodiversity and ecologies, particularly coral reefs and coral islands; (iii) introducing heat-tolerant varieties in aqua-farming; (iv) improving capacity in the management of aqua-farming infrastructure, including fish ponds, ships and ports, in response to disasters caused by climate change; and (v) upgrading the existing and develop new aquaculture logistic services sites (MONRE, 2010). Further, MONRE (2010) identifies several both short-term and long-term strategies including offering better access to weather forecast bulletins; and establishing insurance funds to mitigate climate change and natural disaster risks in aquaculture.

Due to the characteristics as capital intensive and rapid growth, the climate change adaptation in aquaculture is likely to be autonomous with the costs of adaptation are likely to be borne by operators. The autonomous strategies may be better feed conversion, improvements in marketing and upgrading of dykes to reduce flooding and salinity. It also could be more water pumping by semi-intensive and intensive shrimp producers to maintain water and salinity levels. It is estimated that annual cost of climate change adaptation for aquaculture sector in the country is around US$ 130 million for the period of 2010-2050 (WB, 2010).

2.4. Peri-urban Aquaculture in Hanoi:

2.4.1. Peri-urban Aquaculture:

According to the FAO (1995) aquaculture may be defined as “the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as the regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated”. Peri-urban aquaculture captures a broad array of activities occurring in peri-urban interface whose areas subject to urbanization. Aquaculture in the peri-urban areas in a number of cities across Asia includes fish farming and the considerable cultivation of aquatic plants/ vegetables, often using wastewater.

In common, describe the nature of aquaculture occurring in urban or peri-urban areas is described with three types of production systems (Coche, 1982; Edwards, 1993). Extensive aquaculture is characterized by the dependence of stock on natural food; semi-intensive production involves fertilizer applications to enhance natural food production and/or the provision of supplementary feed, which is usually low in protein; and culture in intensive systems relies almost exclusively on an external supply of high-protein feed.

2.4.2. Current status of peri-urban aquaculture in Hanoi

Hanoi with more than 5,100 ha of water surface area has great potential for aquaculture development, with various types of practices such as in ponds, reservoirs, urban lakes, rice fields, or wastewater-fed areas. Because of urbanization, while traditional aquaculture such as fish culture in ponds in urban areas is decreasing, in peri-urban areas intensive aquaculture such as aquatic vegetable production, different types of fish culture and integrated farming is increasing because of conversion of lowland rice fields (T. D. P. Nguyen & Pham, 2005). Fish and aquatic vegetables production utilizing the city's wastewater has an important role in providing incomes and livelihoods for farmers in peri-urban Hanoi (T. D. P. Nguyen & Pham, 2005). More importantly, a large number of individuals and households, especially people of lower socio-economic status, are involved in production and marketing of wastewater-fed aquaculture (Edwards, 2005). Moreover, it is estimated that the cultivation of fish and aquatic vegetables in peri-urban Hanoi meet around 47% and 100% respectively of demand for fresh fish and vegetables of urban consumers, which contributes greatly to urban food supply (van den Berg et al., 2003). More notably, those products are also consumed by a significant number of people, especially the poor (Edwards, 2005).

The water sources which supply aquaculture in Hanoi come from the wastewater-fed rivers and irrigation systems from the Duong and the Red rivers. In Hanoi, wastewaters (mainly untreated) are used for aquaculture since 1960s as a cheap and reliable source of both water and nutrients (Hoan & Edwards, 2005). Peri-urban Hanoi aquatic food production activities using wastewater are concentrated in Thanh Tri district, south of Hanoi where 80% of employment is still agriculture and aquaculture (van den Berg et al., 2003) and about 350 ha of wastewater-fed fish ponds provide fishes for urban consumers in Hanoi (Anh et al., 2007; Hop et al., 2007). Most of wastewater from Hanoi including domestic wastewater collected through a sewage system as well as industrial effluent from many nearby factories which is discharged without formal treatment run into the To Lich river system consisting of the four rivers Kim Nguu, Set, Lu and To Lich (Anh et al., 2007; Marcussen, Ha, Polprasert, & Holm, 2012).

Recently aquatic production in peri-urban Hanoi has been increasing in both overall area and yield. The majority of fish production occurs in Thanh Tri district (52%) whilst the remainder from urban lakes and other nearby districts such as Tu Liem, Gia Lam, Dong Anh and Soc Son districts. There are several types of fish culture in Hanoi including wastewater-fed fish culture whose areas are concentrated in the southern Thanh Tri district; non-wastewater culture; integrated aquaculture; rice-cum-fish production; and fish and prawn culture. The average productivity of wastewater-fed fish culture in Hanoi is increasing from 4 tons/ha/year in 2000 to 5.4 tons/ha/year in 2004 (T. D. P. Nguyen & Pham, 2005). Different fish production systems have contributed greatly to urban fish supply such as fish ponds contributed 46%, wastewater-fed fish 31%, rice-cum-fish 13%, fish in urban lakes 7%, etc. (T. D. P. Nguyen & Pham, 2005).

In terms of aquatic vegetable production in Hanoi, it is mainly concentrated in Thanh Tri and Gia Lam districts. Aquatic plants are often used including water spinach, water mimosa, water dropwort and water cress, in which water spinach is the most important aquatic vegetable produced throughout the year and most preferred by urban consumers. Almost water spinach is produced in wastewater canals and the rotation of these crops is becoming more popular because of the benefits of increased and diversified incomes. Due to the close proximity to city’s market, aquatic plants production in peri-urban is the major source supplied fresh vegetables to urban Hanoi.

In order to meet the increasing demand of urban consumers, the aquatic vegetable producers have extended in areas and depth of their fields to increase productivity and their water source is mainly wastewater pumped from irrigation canals (T. D. P. Nguyen & Pham, 2005).

2.4.3. Impacts of urbanization to aquaculture in Hanoi

One of the main determinants which results in the threats to water source for peri-urban aquatic production is the process of urbanization and industrialization. The first effect which the urbanization process brings to peri-urban aquaculture sector is population growth, leads to the decrease amount of land available for aquaculture, causing an increase in land prices and forcing farmers to intensify their land use (van den Berg et al., 2003). Second, the demand for food products and urban waste, especially domestic wastewater are also increase. According to van den Berg et al. (2003), in Thinh Liet commune of Thanh Tri district where has as much water as agriculture land, Hanoi city government took about 46% in the total amount of 185 hectares for building a new lake in order to receive water from the built-up area of Hanoi in flooding time and to allow heavy metals carried by one of the heavily polluted rivers to settle down before the water is released into the Red River. Thus, the water use for agriculture and aquaculture has to change purpose for urban growth. Moreover, fishponds land was approached by urban development agency of Hanoi to transform to large-scale projects such as housing, factories, etc.

Impacts of wastewater reuse to aquaculture in Hanoi

As mentioned above, dependence largely on wastewater for aquatic production brings high risk for farmers. The decrease in water quality might lead to the poor quality of fish with a bad smell and taste (Edwards, 2005). Besides, as urban consumers' demand for large fish increases, small fish raised in wastewater-fed ponds are difficult to market in Hanoi, mainly sold to poor people. In terms of aquatic vegetables planted in wastewater, although this remains the major sources of fresh vegetable supply for urban consumers in Hanoi, most consumers have been unaware of their origin (Edwards, 2005).

Another important challenge for wastewater-fed aquaculture is using wastewater sustainably to minimize the negative impacts on human health. Epidemiological studies in different countries have shown that the highest risk to human health of using wastewater in agriculture and aquaculture is posed by helminth infections and skin diseases (WHO, 2006). There has been quite number of studies about health risks of wastewater use in peri-urban agriculture and aquaculture in Hanoi. For instance, in order to examine wastewater exposure is a risk factor for skin problems, especially dermatitis among farmers engaged in peri-urban aquatic food production in Hanoi, Anh et al. (2007) conducted a cross-sectional study in two peri-urban communes, one using wastewater and another using river, rain and well water for their production. The result was that using wastewater is an important risk factor for dermatitis among those farmers. Furthermore, by implementing a cross-sectional study in a peri-urban area in Hanoi, Trang, Mølbak, Cam, and Dalsgaard (2007) found out that exposure to wastewater did not pose a major risk for helminth infection in the community. Rather than contacting with wastewater, lack of sanitation facilities and use of fresh or inadequately composted human excreta in agriculture or aquaculture were important risk factors.

Despite the fact that, normally, polluted effluents are not directly fed to fish meant for human consumption, samples of fish from the area, and which are meant for human consumption, do sometimes contain overly high concentrations of heavy metals. In a study of wastewater-fed ponds in peri-urban areas in Hanoi, it is found out that fish raised in peri-urban wastewater-fed aquaculture systems are at risk of infection with fishborne zoonotic trematode (FZT), which can be transmitted to humans through consumption of raw or improperly prepared fish (Hop et al., 2007). In spite of low prevalence comparing to FZT previous findings in non-wastewater fish in Vietnam, consuming wastewater-fed fish has been still an important concern for consumers. Regards to aquatic vegetables, although urban consumers are quite concerned with quality of these products, most of consumers have been unaware that many aquatic vegetables are produced in wastewater, even with chemicals (T. D. P. Nguyen & Pham, 2005).

2.4.4. Impacts of extreme climatic events to aquaculture in Hanoi

There are limited studies on the climate change impacts on peri-urban aquaculture in Hanoi. The major study about the damage loss of the 35-year recorded flood happened in November 2008 in Hanoi, which including the loss in aquaculture. Persistent and prolonged rainfall over the 72h had caused widespread flooding in cities and provinces in Vietnam, including Hanoi (IFRC, 2008a, 2008b; Tuan & Duong, 2009). Heavy rains battered the Hanoi with falls up to 450mm in major streets and roads. The rainfall was out of season, as the monsoon was considered to be over by that time with the astonishing amounts of recorded 700mm rainfall in Hanoi in just 3 days. The water level of a number of rivers (the Red, Nhue, Duong and Cau) increased to alarming levels (nearly 14 meters). In order to cope with the situation, the Hanoi authorities decided to open the Day river barrage to divert waters away from Hanoi, rapidly flooding then early diversion zone within a matter of hours (McElwee, Nghiem, Le, & Vu, 2009). IFRC (2008a, 2008b) reported on the basis of government information that there were 85 casualties and that 20,000 families were affected. Total losses were estimated at US$ 500 million. Aquaculture proves to have suffered the most in the flood. The north saw 27,000 ha of aquaculture complete lost with the flood, of which Hanoi has lost 9,000 ha. A lot of farmers have suffered financially from the flood, unable to collect any income. A household breeding fish in Thanh Tri district complained that they had lost several hundreds millions VND (about few thousands US dollars) (FishSite, 2008). Another research studied the influence of flooding on agriculture and aquaculture systems in two different sites in the city. The results also showed that aquaculture was affected by the rapidity of the flood. While this source of income was smaller than livestock or agriculture for most households regards to overall income contribution, the damage in aquaculture was highest as a percentage of income. The study also explained that the floods often swept away fish which make fish farmers not only lost the ability to sell fish but also wipe out the investment that had been made in fish fry (McElwee et al., 2009).

CHAPTER III
FARMERS' PERCEPTIONS OF CLIMATE VARIABILITY IN THANH TRI DISTRICT AND STUDY AREAS

The third chapter of the research aims to response to the first research questions: *"What are farmers' perceptions of changes in climate variability?"*. First, the chapter describes the background of two studied communes to understand the physical and ecological characteristics of the study areas including its particular geographic features. These characteristics are necessary to comprehend because of its important role in determining climate and other social and economic factors. Further, the chapter studies the aquaculture development in the communes with the brief illustration on historical processes, culture systems and major risks related to each system. Second, the chapter explores the perceptions of farmers in climate variability in the district in general as well as in the communes in particular. Farmers perceived climate variability with general changes and with three specific climatic factors including temperature variability, rainfall variability and extreme events. Besides, in order to evaluate the farmers' perceptions, the chapter combines simultaneously with institutional knowledge about climate record in the area to validate the similarity or difference and explores the reasons behind. In order to comprehend more details about the perception, the causes of those changes are mentioned.

3.1. Background of the study area

3.1.1. Physical and Socio-economic Characteristics

Geographic characteristics

Dong My and Tu Hiep communes in Thanh Tri District were chosen according to its different fish culture systems and farming scales. Dong My commune (Figure 6) has the natural land of 273.6 ha and its boundaries to the Red River in the northwest and adjacent to other communes of Thanh Tri district in the south, east, and northern. Tu Hiep commune (Figure 7) has the natural area of 410.9 ha and borders with Tam Hiep commune in the west, Ngu Hiep commune in the south, Yen My commune in the east and Hoang Mai district in the north.

Figure 6: Map of Dong My Commune

Source: Google Map, 2015

Figure 7: Map of Tu Hiep Commune

Source: Google Map, 2015

Overall, the terrain of the Thanh Tri district as well as two chosen communes is relatively flat with the slope from 0°-3°, and average height to the sea level from 4-5m. Some parts of the district remain the natural terrain of previous area before the formation of Red River dyke, whose surface was composed as a basin. Located in the South of the Hanoi city as well as in the lowest-lying area towards natural flow of surface water and ground water of Hanoi from west and northwest down to south and southeast, Thanh Tri district carries all the water resource from rain water to discharged wastewater, which is main water source for irrigation systems in two communes. Water flows go through the district from four rivers including Set, Lu, Kim Nguu and To Lich. In addition to low-lying terrain which difficult digests water, the district has been receiving the largest and increasing amount of wastewater from urban areas.

On one hand, the particularly geographical location and terrain surface seems to determine naturally the economic and environmental functions of suburban or peri-urban Thanh Tri district. On the other hand, because of the terrain characteristics as a basin, water logging phenomenon such as floods is inevitable. However, this also creates an advantageous condition for aquaculture development in the district as well as plays an important function in harmonizing the weather due to opening surface of large number of ponds or lakes.

Patterns of Land Uses

Since mid-1990s, together with the economic reform ("doi moi") in Vietnam, Thanh Tri district became an urban expansion area of Hanoi, called suburban or periphery/ peri-urban area. As similar as other periphery areas in Asia, the district experienced the rapid changes in land use, especially to agricultural land pressured to be converted to other uses. Table 6 illustrates the changes in land use in Thanh Tri District from 2003 to 2014. Noticeably, the agricultural land descends considerably by about 240 ha from 3,548 ha in 2003 to 3,308 ha in 2014. In 2014, the aquaculture area in the District is 829.96 ha, in which Dong My commune and Tu Hiep commune have largest land with 122.03 ha and 127.1 ha respectively (GoV, 2015).

Table 6: Changes in land use in Thanh Tri District from 2003 to 2020

No.	Year	2003	2007	2014	2020 (planned)
1	**Agricultural land (ha)**	**3,548.13**	**3,462.13**	**3,308.02**	**1,903.06**
1a	Aquaculture land (ha)	n/a	n/a	829.96	626.65
2	**Non-agricultural**	**n/a**	**n/a**	**2,957.90**	**4,362.75**

	land (ha)				
3	**Unused land (ha)**	**n/a**	**n/a**	**27.78**	**26.9**
	Total area (ha) **= (1) + (2) + (3)**	**6,292.71**	**6,292.71**	**6,292.71**	**6,292.71**

Source: Dinh (2010), GoV (2014) and GoV (2015)

Regards to land use pattern in the future, the district was approved by the city government to implement Land Use Planning until 2020. Table 8 demonstrates the agriculture land would decrease remarkably from 3,308 ha in 2014 to 1,903 ha in 2020, in which aquaculture area would significantly ascend from 829 ha in 2014 to 626.7 ha in 2020. Considerably, the aquaculture production has been planned to focus on aquaculture zones including Dong My commune which would be received investment of city government in infrastructure and aquaculture development. In contrast, current aquaculture land in areas for urban planning including Tu Hiep commune would be replaced for non-agricultural land use especially for infrastructure development and housing projects.

Furthermore, there is significant difference in agriculture land use right between two communes. In Dong My commune, most farmers are distributed land based on quotas for local farmers. The agriculture land in the commune is allocated by state with household contract system for a period of 20 years. Each household is leased about 0.5 sao/person (1 sao = 360m2) agriculture production land. For aquaculture farmers, they often lease more land from other farmers to operate aquaculture systems. Farmers in the commune pay annual fee around 7 million VND (US$ 350) per ha. In Tu Hiep commune, a majority of farmers lease the land of other farmers or cooperatives in agreement of the rental fee. Cooperative land is placed on the bidding to allocate for individuals or groups of farmers bidding highest, for a period of only five years. Normally the fish farmers pay to the cooperative 100kg rough rice/sao/year. In some cases, fish farmers directly make contract with other farmers with the rental fee agreement, then these farmers have to pay to the cooperative 15kg rough rice/sao/year for agriculture services.

Climate

Belongs to Northern Delta, hydrological climate condition of Thanh Tri District and two communes brings characteristics of Red River Delta as typical tropical monsoon with two main seasons per year: hot and cold season. The hot and humid season starts from April to October and filled with heat, humidity and much rain (O. V. Nguyen, Kawamura, Phan, Gong, & Suwandana, 2015). Thus, the hot season is usually the rainy season. The cold and relatively dry season starts from November to March. According to Chinese calendar, the district climate consists of 4 seasons including summer (June – August), autumn/fall (September - November), winter (December – February) and spring (March – May). The maximum temperature reaches to 38°C - 40°C and the minimum temperature during cold season excesses to 6°C - 7°C with no chilly wind.

The average annual rainfall is 1,649mm and 70 percent of total amount of rainfall concentrates in the hot and rainy season, thus the district additional prone to the risk of water-logging or floods. The southeast and northeast wind are two main wind season in the year. Every year, the district affects directly of 5 to 7 storms. The strongest storms are up to 9^{th} or 10^{th} level causing major damage to agriculture activities in the district. Storms are usually coincides with the rising water season of Red River which threatens not only agriculture production but also lives of people. Due to strongly affected by monsoon climate, the weather in Thanh Tri is considered as fluctuated, significantly impacts to agriculture and aquaculture production. However, the cold and dry winter in the district only last for short time in early winter, early spring temperature becomes warmer and haves drizzles with high humidity.

Dong My and Tu Hiep Commune has the same climate characteristics as Thanh Tri district with two main seasons including hot/ rainy season and cold/ dry season. Further, because of the geographical features of two communes in low-lying area, both communes are at risk of heavy rain or floods. More considerably, due to strongly affected by monsoon climate, the weather in two communes is also considered as fluctuated which likely affects aquaculture production. The impacts of these fluctuations would be explored details in the next chapter.

Socio-economic profile

The total population of Dong My commune is around 10,420 people in 2014[2]. Average annual income per person in the commune is 25 million VND (US$ 1,250). The commune itself accommodates very few industrial facilities and its main economic activities are based on agriculture. Dong My has an agriculture economy where approximately 60% of the labor force are engaged in farming activities, of which rice cultivation, fish farming, vegetable and subsidiary crops, as well as livestock are the most important. Of this 63% are agricultural labor, 5% are fish farmers (with the majority being men), and 58% are doing agricultural field work (women are dominant here). The rest of the commune's work force (about 37%) is distributed to other occupations including construction workers, carpenters, small traders, businessmen, trap makers and administrative employment. However, because of its location and low income from purely agricultural work and a large amount of agricultural leisure outside the farming season, many farmers, especially the young and middle – aged group are now doing both farming and factory work at the same time.

Tu Hiep commune has average population is nearly 14,000 people. Average annual income per person is 29.5 million VND (US$ 1,450)[3]. Although the agriculture land has descended and land price in Tu Hiep has increased due to the urbanization process of Hanoi city, large amount of agriculture and aquaculture still remaining and contribute sufficient income for local farmers.

3.1.2. Aquaculture production in Dong My and Tu Hiep Commune

Historical development

Aquaculture in Thanh Tri district has changed with time because of socio-economic factors and technology improvements. Vo and Edwards (2005) provided the comprehensive historical review of aquaculture development in the district with

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[2] Dong My Commune People Committee (2014) Report on Socio-economic achievements and challenges

[3] Tu Hiep Commune People Committee (2014) Report on Socio-economic achievements and challenges

which practices wastewater reuse started from 1960s. From early 1960s to late 1970s, the aquaculture using wastewater practiced widespread with mainly rice-fish culture because rice could not be cultivated year around in flood, low-lying area. At that period, a number of cooperatives were formed and expanded while farm land was used communally. From early 1980s, land use was changed from cooperative to individual household management. The majority of cooperative land was shared among individual households for their use based on the number of household members. The rest of the land (about 10%) was bid for private use. Cooperative land, which often included large water bodies, was allocated competitively to individuals or groups of farmers bidding the highest, for a period of five years. Due to insecurity in land tenure which leads to inadequate farm investment, household contract system was introduced in 1988 to extend the leasing time to 20 years. Further, at the same time, cooperative subsidies in wastewater distribution to fishponds were also stopped. Thus, since then, each farm needs to arrange to attain wastewater by itself, which causes difficulty to farms far from the river. Currently, aquaculture practices in Thanh Tri district still mainly depend on wastewater as major water resource.

Most of aquaculture farms in Dong My commune started from 2000 since the commune implemented converting low-effective agriculture land with 2 crops per year to aquaculture production. Majority of farm sizes in the commune are smaller or equal 2 ha (95.9% of total 121 farms) and only 4.1% of total farms have areas greater than 2 ha[4]. In contrast, in Tu Hiep commune, there are only 8 fish farms which are medium and large scales whose areas ranging from more than 5 ha to nearly 40 ha[5]. In both Dong My and Tu Hiep commune, wastewater from the city is used in culture systems for the carps species, as it encourages the growth of algae and other aquatic flora and fauna in which provide a ready source of nutrition for the fish. The wastewater is pumped by the Farmer Cooperative with the farmers paying an annual monthly fee for it. The water used in these fish culture systems mainly comes from precipitation, other ponds and from Hanoi's wastewater canal system.

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[4] Dong My Commune People Committee (2014) Report on aquaculture production
[5] Tu Hiep Commune People Committee (2014) Report on aquaculture production

At certain times especially in the dry season, use of more concentrated wastewater without adequate dilution can result in high fish mortalities resulting in considerable financial loss. Further, in terms of human resource in fish farms, most of labor used is provided by permanent staff but additional rented labor is only used during busier periods of harvesting and pond preparation.

Fish culture systems

The fish culture cycle usually runs for 10-11 months, from March or April to January or February. Farmers drain ponds after the harvest in January or February, wait for 1 to 3 weeks for drying, then clean, lime and refill with water. After three months stocking fish, households begin to harvest mainly for sale and minor for domestic consumption. Most of households have two or three production cycles per year (T. D. P. Nguyen & Pham, 2005). According to the different types of land use, fish farming systems in Thanh Tri are often divided into four types: fish only; integrated with garden and livestock; rice-cum-fish; and fish seed or fingerlings. This classification of farming systems supported those described by Pham and Vo (1990), Vu (1994), Dalsgaard (1996), Edwards (1996) and T. D. P. Nguyen and Pham (2005).

- Fish only system

This fish culture system produces fish for food only, which was majorly farmed in large water bodies such as lakes or reservoirs. The systems usually use wastewater as major water source and rain or storm water in rainy season as an alternative source. Noticeably, communes conducting this culture system often have long tradition of fish farming and wastewater reuse which consists of both Dong My and Tu Hiep communes where the study conducted. Furthermore, in Thanh Tri district, this type of culture expanded to newly developed aquaculture areas without wastewater supply system including some farms in Tu Hiep commune. Without wastewater, farmers need to fertilize fish ponds and feed the fish with other inputs including both on-farm and off-farm supplementary feeds. Farms practicing this culture system have area ranging from 0.36 ha to 29.84 ha, with a mean of 7.1 ha (Vo & Edwards, 2005).

- Integrated system

This system has been practiced in Thanh Tri district at household level and based on the concept of "VAC" which is short for a Vietnamese term of "Vuon – Ao – Chuong" means Garden – Pond – Livestock Quarter system. In the integrated system, farmers raise livestock such as chickens, pigs or ducks adjacent to or above fish ponds, thus ponds also benefit from spilled feed and manure. Besides, farmers often plant fruit trees and vegetable around pond dykes so that nutrient rich mud from drained pond bottoms can be used to spread over the pond dykes to further recycle wastes. This culture system is likely recommended because of the benefits in escalating productivity as well as diversifying income for farmers. Some communes in the district have conducted this type of system such as Tam Hiep, Van Phuc, Dong My, etc. (T. D. P. Nguyen & Pham, 2005).

- Rice-cum-Fish System

This system is the oldest fish culture system in Thanh Tri district. The rice-cum-fish culture systems require a large amount of land area with the mean farm size of 27.1 ha (Vo & Edwards, 2005). Thus, the systems are conducted mainly on cooperative land shared by groups of farmers. The advantages of the system are suitable for lands far from rivers, thus lack of wastewater supply and creation of more jobs and income for farmers with lower risk than the fish only system. This also implies that farms practicing this system highly prone to fluctuated changes in climate as its dependency on weather for water resource in both crops and fish production. The major disadvantage of the system is the complexity in managing farms because of separation ownership between fish culture and rice cultivation. Further, due to the requirement of large land area, the decreasing trend of agriculture land in the district in recent years and future might lead to the reduction in practicing the system.

- Fish seed or Fingerling System

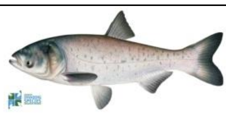
This production system can be practiced in small farm area, with a mean farm size of 0.48 ha and a range of 0.1 – 2.9 ha (Vo & Edwards, 2005). In Thanh Tri district, fish farmers in some communes, especially in Dong My, specialized in nursery ponds and producing fingerlings for individual households for on-growing into food fish (T. D. P. Nguyen & Pham, 2005). The system has advantage in small scale, low capital investment, simple technology but potentially generate high income (Vo & Edwards, 2005). However, farmers specializing in this system face the challenges of water quality because fry is very sensitive to variable quality.

In Dong My commune, because of the small farm areas, the fish culture systems farmers in the commune are conducted mainly fingerlings and fish only system. Furthermore, fish farmers in Dong My also have practiced integrated system with VAC model following the aquaculture development plan of the district. More notably, since 2000, some farms obtained giant freshwater prawn culture with the support from Hanoi's extension models in the district, with the average yield of 1.8 tons/ha. However, after 4-5 years, the number of farmers practicing this system reduced sharply because of the decline of water quality and the fluctuation of climate while the prawn is really sensitive to climate and water quality. In Tu Hiep Commune, because of large size of farm areas, the farmers often practiced the fish only and rice-cum-fish culture system. Both systems require high inputs comparing to culture systems in Dong My commune.

Fish species

Most farmers in Dong My and Tu Hiep communes culture fish species including common carp, silver carp, grass carp, Indian carp (rohu and mrigal), mud carp, bighead carp, tilapia, and Colossoma. A small number of farmers stock high-value black carp because of few available snails for feed (T. D. P. Nguyen & Pham, 2005). Table 7 describes basic characteristics of fish species which is necessary to understand the relationship between changes in climate and its impacts to particular species and the way farmers adapt with it.

Table 7: Characteristics of fish species

Type of fish	Water	Optimal temperature range	Oxygen concentration	Photo	Source
Common carp *(Cyprinus carpio)*	Freshwater or slightly brackish water	3°C - 35°C	low		FAO Invadingspecies
Silver carp (*Hypophthalmichthys molitrix)*	Freshwater Backwaters of large rivers	6°C - 28°C	High		FAO Invadingspecies
Grass carp (*Ctenopharyngodon idella*)	Freshwater	? - 35°C			Fishbase Invadingspecies
Indian major carps (mrigal)	Freshwater, brackish	14°C min	low		Fishbase Punjabfisheries
Indian major carps (rohu, Labeo rohita)	Freshwater, brackish	16°C - 37°C 13.9°C min			Fishbase Anglinginbangladesh
Bighead carp (Aristichthys nobilis)	Freshwater				Invadingspecies
Black carp (Mylopharyngodon piceus)	Freshwater				Invadingspecies

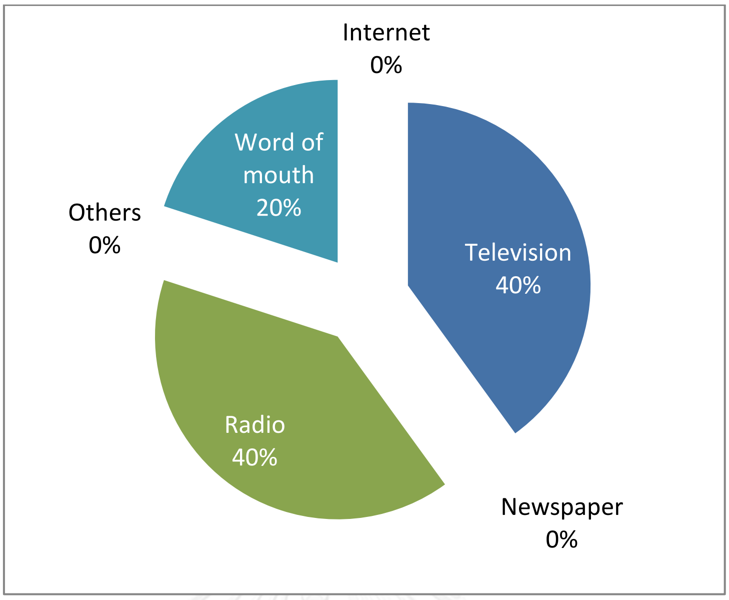
Nile Tilapia (Orechromis niloticus)	Freshwater, brackish	13°C - 33°C (natural) 8-42°C (extended)			Fishbase Urban fishfarmer
Colossoma *(Colossoma macropomum)*	Freshwater	10°C - 25°C 6°C min			Fishbase

3.2. Farmer's perceptions on climate variability in Thanh Tri District:

3.2.1. Perceptions on the General Changes in Climate

With the regards of general knowledge or acknowledge related to climate changes, 69 percent of interviewed farmers have heard about the term "climate change" before while the rest (31 percent) responded that they have not known about it. Television and commune radio are two most popular communication channels the farmers receive information about the phenomenon. In those 69 percent, 40 percent knows about changes through television with national channels or programs discussing on the issue, another same amount of farmers listen to the commune radio which broadcasts daily and the rest hear from word of mouth from neighborhoods or work colleagues (Figure 8).

Figure 8: Which channels do you know about climate change?



Source: Field survey (Huong Ngoc Nguyen, 2015)

Amongst the farmers took notice of the phenomenon, most of them perceive that "climate change" is defined as the abnormal climate variation, especially related to temperature, rainfall and some extreme events which consequently affect to their aquaculture production. The term "climate change" is translated as "biến đổi khí hậu" which means "climate transforming" and used in most of official reports as well as studies in local language (Vietnamese). The term "biến đổi khí hậu" thus was explained to farmers who have not heard about that in clearer and easier way as the abnormal weather or changes in frequency and intensity of climate factors in long-term (about 20 to 30 years). After that process, similarly, most of those farmers also perceived "climate change" as changes of temperature, rainfall and several extreme climatic events. Therefore, it is likely that fish farmers in two communes are becoming increasingly concerned about local climate variability. However, most of interviewed farmers relied on recent climate variability in short-term (for 5-10 years) instead of long-term changes in climate. This perception was found in other studies of Bryan, Deressa, Gbetibouo, and Ringler (2009) and Gbetibouo (2009).

The foundation of their perception from the memory about their past experience and from the information they acquired from above communication channels. Furthermore, while some farmers sense the weather changes in terms of the specific tremendous events, others think the changes regards to the intensity and frequency in climate. Regards to the farmers who have never heard about the term "climate change" before, interestingly their perception about examples of climate change occurrence mostly based on their memory and experience about current or most recent climate they have to deal with.

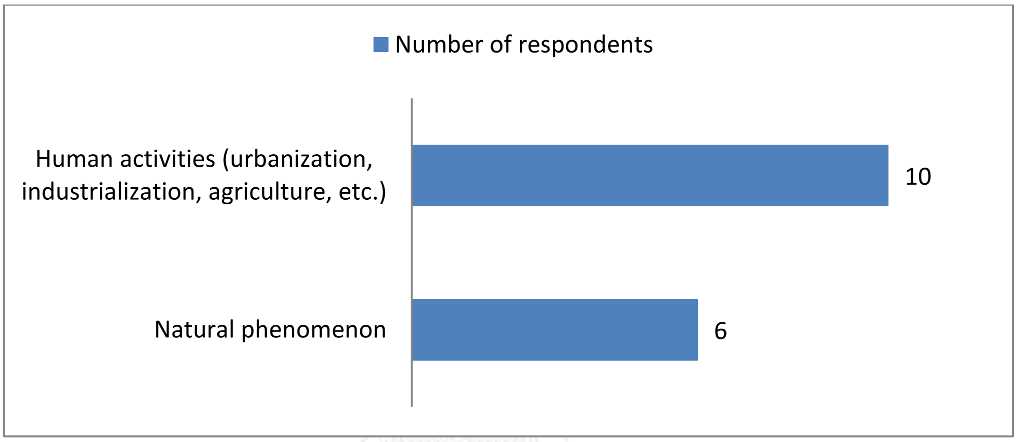
> "I heard on the TV that climate change could be the acid rain which causes by air pollution."
>
> *(FF#4, 3rd June, 2015)*
>
> "I remember most is the flooding in Hanoi in 2008 due to heavy rain and its long-lasting time"
>
> *(FF#7, 4th June, 2015)*
>
> "I think that climate change is the phenomenon in which the weather changes unusual and abnormal. The most obvious event is the hot period last month which last more than 10 days"
>
> *(FF#2, 2nd June, 2015)*
>
> "The weather is changing in a great deal years by years. Especially these recent three year, the temperature is getting hotter."
>
> *(FF#4, 3rd June, 2015)*

In order to comprehend the profound perception, farmers explain the reasons causing climate change phenomenon or changes in weather they perceived. Particularly, 62.5 percent of total 16 interviewees pointed out human activities are causes for changes in climate in the area while the remainder of 37.5 percent believed that climate change are natural phenomenon (Figure 9). Some attributions are referred to human activities including urbanization or increasing growing urban population, industrialization or agriculture activities surrounding.

"I can call the development here as "sand-ization" (agriculture land turn to construction land). If the bubble real estate crisis in 2008-2009 did not happen and food security became one of priority of State, there might no aquaculture farms here anymore. The reason is the very high speed of urbanization. Every land is in urban planning".

(FF5, 3rd June, 2015)

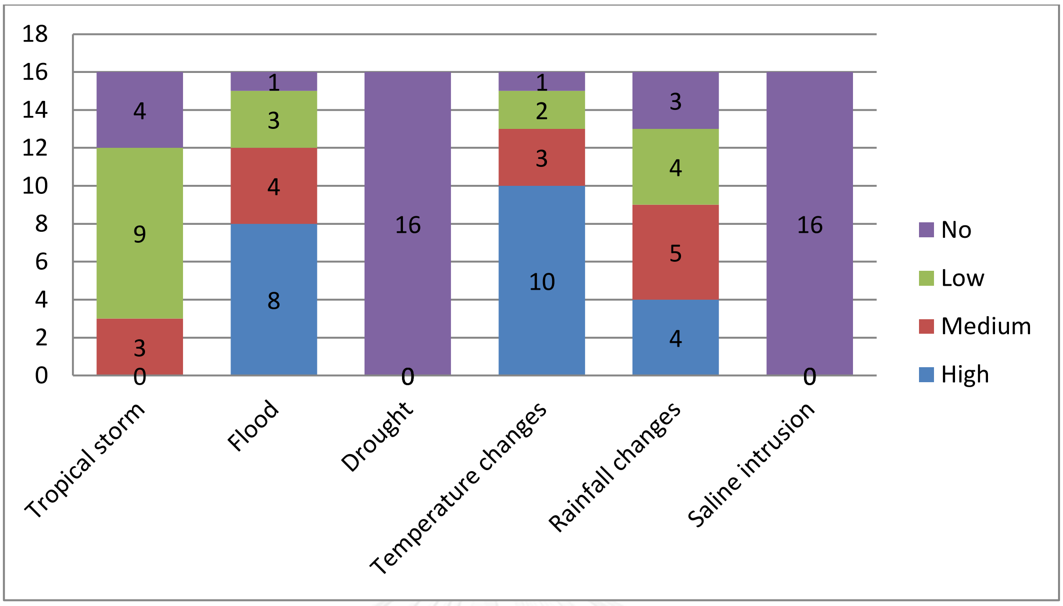
Figure 9: Perceived causes of changes in climate



Source: Field survey (Huong Ngoc Nguyen, 2015)

With the purpose of understand specific perceptions, the following section describes the farmers' viewpoints on changes in different climatic factors, namely temperature, rainfall and extreme events. The study chooses those climatic factors because farmers ranked temperature changes, rainfall changes and floods affect most to their aquaculture production and output (Figure 10).

Figure 10: Climatic changes affect most to aquaculture production and output

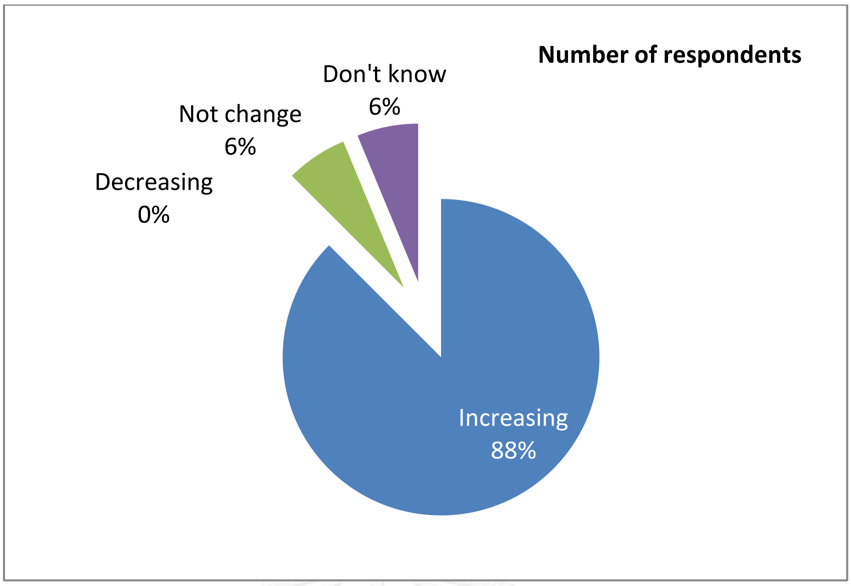


Source: Field survey (Huong Ngoc Nguyen, 2015)

3.2.2. Perception about Changes in Temperature Variability

In this section, the data was analyzed according to the semi-structure interview to farmers in both Dong My Commune and Tu Hiep Commune to explore their perceptions on changes in temperature variability. As a result, increasing trend of temperature is dominant perception with 87.5 percent of interviewed farmers expressed that temperature in the area tends to ascend long-term (Figure 11).

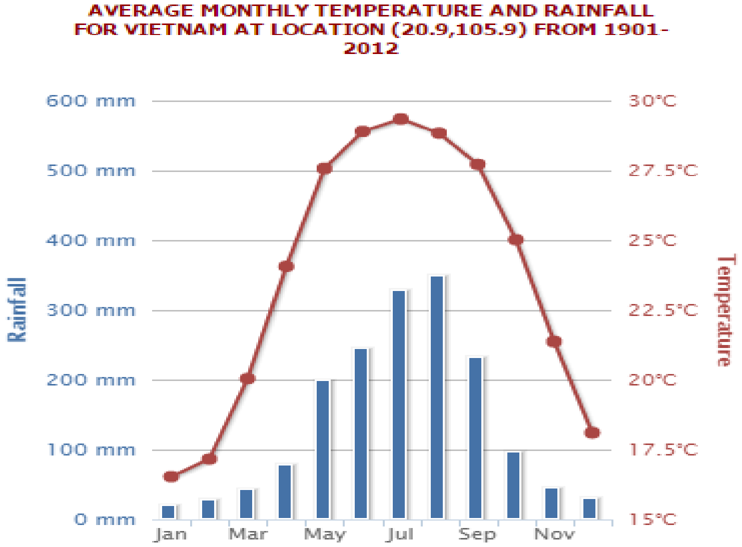
Figure 11: Farmer's perception on temperature changes in Thanh Tri District



Source: Field survey (Huong Ngoc Nguyen, 2015)

According to both statistic data and farmers' perception, the hottest months in the year are from June to August in which the month with the maximum highest temperature is July, and the coldest months in the year are from December to February and the month with minimum lowest temperature is often January (Figure 12).

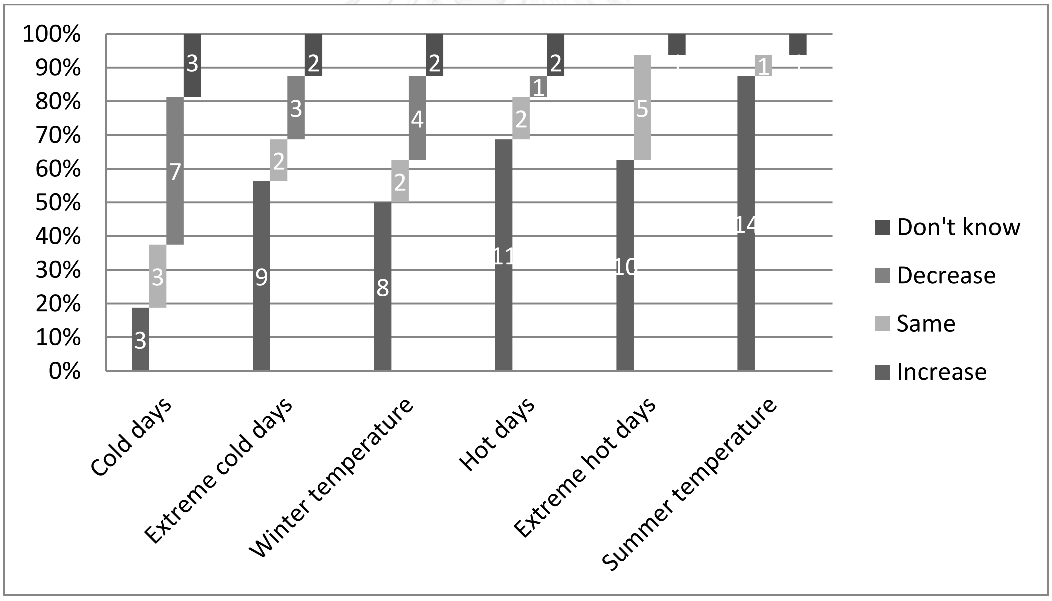
Figure 12: Average monthly temperature and rainfall in Thanh Tri district from 1901 to 2012



Source: WB (2015)

Particularly, Figure 13 illustrates the changes in different temperature indicators in the area perceived by fish farmers. Both summer temperature and winter temperature was perceived to have a rising tendency. The number of hot days and extreme hot days were identified to be increasing, especially in recent 5 years from 2010 to 2015. Significantly, in 2014 and 2015, the high temperature is felt visibly last for 10 to 15 days continuously with the average temperature of 39°C. Overall opinion about winter temperature is that farmers felt warmer in winter, especially in current 2 years from 2014-2015. Interestingly, while most of farmers noticed that number of cold days decrease, they highlighted that the extreme cold days was increasing. This affects both negative and positive impacts on their aquaculture production which would be discussed in the next chapter.

Figure 13: Changes in different temperature indicators as perceived by farmers



Source: Field survey (Huong Ngoc Nguyen, 2015)

In addition, the interviewees explained about the causes of changes in temperature by pointing out the influence of urbanization to the communes with external and internal forces. Regards to external forces, urban growth made the significant changes in the communes' land while Thanh Tri District had been considered as peri-urban instead of rural area. While the construction land for urban purpose has increased and replaced agriculture with a large amount of land area, more investment in infrastructure such as concrete roads was provided for the communes which is perceived to make temperature hotter comparing to the past while they have only temporary road by. More notably, some farmers in Dong My commune noticed that the temperature in summer months such as May and June is getting hotter due to agricultural activities, which could be explained by the mixed economic activities in the district as the characteristics of peri-urban areas.

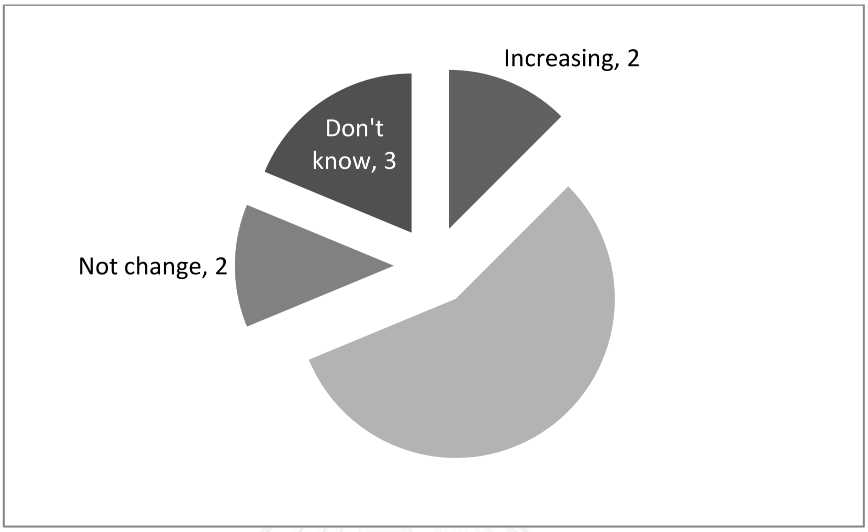
> "Every May and June, rice farmers burn straw all days and nights which makes the temperature becomes higher. I feel that the temperatures at day time and night time are not so different"
>
> *(FF#8, 5th June, 2015)*

Besides, in terms of internal factors, some thought that the changing in temperature also is caused by the local residents' activities. For example, under the urbanization process, people in the district filled up a huge number of lakes and ponds within the district and communes itself for house construction, which makes weather cannot be harmonized. The phenomenon of increasing trend in temperature also affected from the wind changing with the rising frequency of Western wind (often called "Laos wind") in summer months, especially during two years 2012-2013.

3.2.3. Perception about Changes in Rainfall Variability

In this part, the primary data analysis focused on the farmer's perception on changes in rainfall variability during the period of 30 years from 1984 to 2014. As mentioned in the first section, hot season in the district is also usually rainy season. Rainy season often starts from the end of April or beginning of May until October, in which July to September is the time of the year receiving the majority of the annual rainfall (Do, Martens, Luu, Wright, & Choisy, 2014). Interviewed farmers also point out that much rain happens often in the months of July and August in the year, but the amount of annual rainfall is getting less year by year. Nine of total 16 farmers go along with this perception (Figure 14). However, most of medium-scale and large-scale farmers are more concern about rainfall changes than small-scale farmers than because of rainwater as key water source for their aquaculture production.

Figure 14: Perception on changes in total amount of annual rainfall



Source: Field survey (Huong Ngoc Nguyen, 2015)

The viewpoint of farmers matches up with the trend pattern of annual rainfall from 1971 to 2010 in Hanoi in particular and in Vietnam in general. The study of D.-Q. Nguyen et al. (2014) about variations of surface temperature and rainfall in Vietnam from 1971 to 2010 was conducted with the observational datasets provided by the Vietnam National Centre for Hydro-meteorological Forecasting in eight sub-regions, , in which Hanoi belongs to N3 sub-region. Table 8 shows that dominant trends for annual rainfall in N3 sub-region has statistically notable decreases.

Table 8: Estimated trends in maximum, minimum temperature and rainfall from 1971 to 2010

	Tx an.	Tn an.	Tx an. – Tn an.	Dry_ss	Rain_ss	∑ Rainfall
N1	$0.18 \pm 0.09^{*}$	$0.12 \pm 0.08^{**}$	INS	DNS	DNS	DNS
N2	INS	INS	INS	DNS	DNS	DNS
N3	0.21 ± 0.10	$0.12 \pm 0.12^{+}$	$0.11 \pm 0.07^{+}$	DNS	$-91.31 \pm 53.12^{*}$	$-84.40 \pm 66.98^{+}$
N4	INS	INS	DNS	$30.09 \pm 20.54^{**}$	DNS	DNS
S1	DNS	$0.25 \pm 0.15^{***}$	$-0.19 \pm 0.07^{***}$	INS	$174.65 \pm 144.06^{+}$	INS
S2	$0.19 \pm 0.17^{+}$	$0.31 \pm 0.16^{***}$	$-0.21 \pm 0.09^{***}$	$91.34^{*} \pm 94.58$	DNS	DNS
S3	$0.27 \pm 0.17^{*}$	$0.35 \pm 0.15^{***}$	$-0.13 \pm 0.10^{*}$	INS	INS	INS
IS	$0.47 \pm 0.15^{***}$	INS	$0.42 \pm 0.19^{**}$	$127.71 \pm 96.11^{*}$	INS	$199.06 \pm 70.67^{**}$

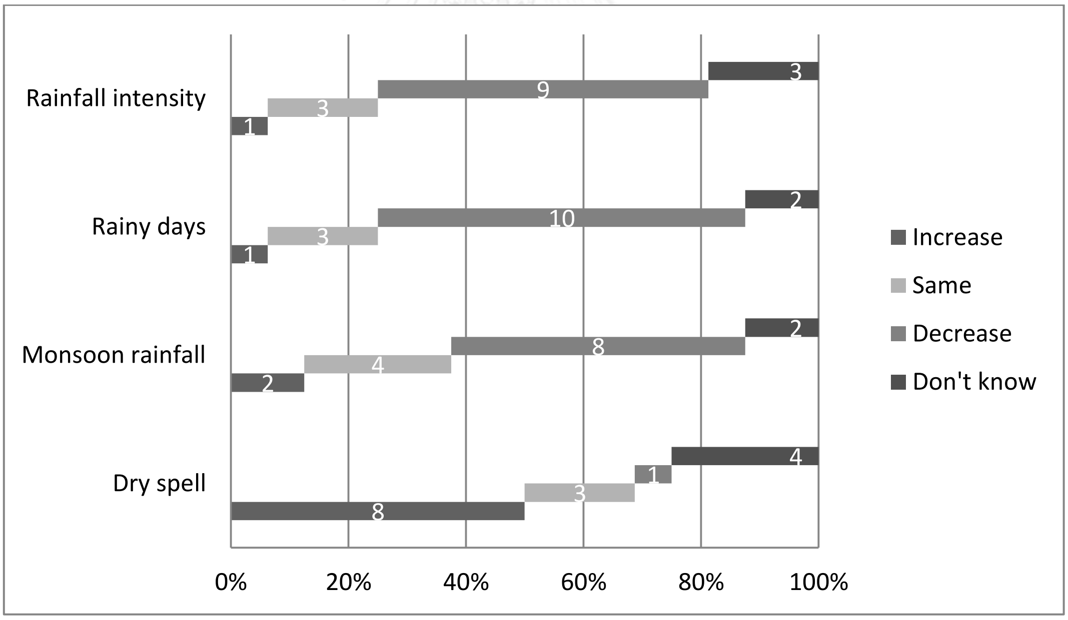
For abbreviations see Table 2. (Tx an. – Tn an.): different temperature between average maximum temperature anomaly (Tx an.) and average minimum temperature Tn anomaly (Tn an.). Dry_ss, Rainfall in Dry Season; Rain_ss, rainfall in Rainy season; ∑ rainfall, total rainfall over 12 months. Unit for changes of rainfall: mm per 10 years.

Source: D.-Q. Nguyen et al. (2014)

In details, Figure 15 demonstrates that rainfall intensity is perceived to largely decrease as same as with the number of rainy days. For aquaculture, monsoon rainfall plays an important role in water resource for fish farmers in the area. However, it was noticed that the monsoon rainfall also tends to decline considerably. Moreover, occurrence of dry spell was recognized to be ascending due to less rainfall and increase temperature.

> "Ten years ago, my fish farm mainly relied on rainfall in rainy season as water resource and preservation for dry season. However, these recent 5 years, the amount of rain is getting less years by years and only concentrated in certain time in rainy season"
>
> *(FF#13, 9th June, 2015)*

Figure 15: Changes in different rainfall indicators as perceived by farmers



Source: Field survey (Huong Ngoc Nguyen, 2015)

3.2.4. Perception about Changes in Extreme Climatic Events

This section centers on the perception of farmers on frequency and intensity of the extreme climatic events happened in the communes during the period of 30 years from 1984 to 2014. Extreme climatic events could be flood, drought, storm, irregular heavy downpours, cold snaps or heat waves. Regards to floods, prior to 2000, only a few farmers mentioned that they remembered the floods in 1984, 1989 and 1997 and the most serious flood was in 1984 which lasted for 20 days. However, because those events happened for long time ago, most of farmers could not remember in details about floods. After 2000, interviewed farmers noticed most about the case of irregularly heavy rain which turns to floods in November 2008.

> "The most affected flood I remember was the one in 2008 when the rain continuously happened for three days then whole Hanoi was shrinking in the water. The water level reached to the height of our bed. My fish pond was also under the water for more than a month. I could not do anything, just came back home and waited for the water level down."
>
> *(FF#11, 8th June, 2015)*

The perception is correspondent with the flood event mentioned in the literature review. That was recorded flood in the period of 35 years caused by long lasting and heavy rainfall over 3 days in not only Hanoi but also across cities and provinces in Vietnam (IFRC, 2008a, 2008b; Tuan & Duong, 2009). Excluded from that 2008 flood, there is general agreement that the frequency of flood decrease because since 2008, there has been no similar events happened in the communes.

In terms of irregular climatic cases, it was perceived that there has been an increasing trend of extreme hot days last for more than 10 days. This could be considered as heat waves phenomenon which is a prolonged period of excessively hot weather. Farmers highlighted that there were heat wave events remarkably happened in summer of 2010, 2014 and nearest 2015. The peak temperature in those events reached even to 41°C. According to secondary data, there were the similarity in the recording those events. For example, O. V. Nguyen et al. (2015) found out the most serious heat wave events occurred in Hanoi was in June 2010, in which a harsh heat wave last 5 days and the day time temperature reached to 41°C and night time temperature was 30.4°C. In addition to heat wave events, farmers also mentioned that cold snaps often happened with intensity of extreme cold days, especially in 2008 and 2013.

> "To me, 2008 was the most affected year because of both cold snap in January and flood in November"
>
> *(FF#16, 11th June, 2015)*

Overall, it could be indicated that fish farmers in the communes have a rising concern about local climate variability. They illustrated their perceptions about the changes in temperature, rainfall variability and frequency and intensity of extreme climatic events mostly based on their memory, direct and current experience with climate factors affected most to their aquaculture production. While ascending trend was perceived in temperature, rainfall was received the opinion of descending trend. Besides, regards to extreme events, it was highlighted that while the events with heavy rain or flooding tend to decrease, other events such as heat waves and cold snaps were considered to be upward trend. However, it is notably that the perception about climate variability of fish farmers in two communes mostly based on the short-time period for about recent 5 to 10 years, not long-term changes. Those perceptions are considered to contribute to next chapter in order to understand the impacts of climate variability and adaptive strategies of fish farmers in peri-urban Hanoi.

CHAPTER IV
PERCEIVED IMPACTS OF CLIMATE VARIABILITY ON AQUACULTURE PRODUCTION AND ADAPTIVE STRATEGIES

In the chapter, by analyzing the primary and secondary data, the research focuses on investigate the perceived impacts of climate variability to aquaculture production, which is needed to understand before exploring adaptive strategies. First part of the chapter would response to the second research question: *"How do farmers perceive the impacts of changes in climate variability on aquaculture production?"*. Fish farmers in two communes perceived that the impact of changes in different climatic factors affects both negative and positive to their livelihoods which major depends on aquaculture. Based on perceived impacts, the second section addresses the adaptive strategies which farmers applied to response to climate variability and its impacts, in order to answer to the third research question: *"What are adaptive strategies do the fish farmers response to the changes in climate variability and its impacts?"*. Last section of the chapter investigates the community adaptive capacity to cope and adapt to current and future changes in climate variability and its impacts. It would be analyzed based on their capital such as physical capital, financial capital, social capital, human capital and natural capital. Based on the analysis, the research discusses on the barriers for the community as well as for farmers in climate variability adaptation, with overall aim to respond to the last research question: *"How adaptive capacity of farmers affect to their adaptive strategies to those changes and impacts?"*

4.1. Impacts of Climate Variability on Aquaculture Production

First part of the chapter concentrates on analyzing the impacts of climate variability perceived by farmers on their aquaculture production and output in both Dong My and Tu Hiep communes. Aquaculture production in two communes is vulnerable to the climate change impacts, largely direct on the productivity. In turn, the impact would affect indirectly to households' income and their livelihoods because income from aquaculture contributes as the major source. Overall, increasing temperature trend could impact on productivity, decreasing the amount of rainfall might lead to stress on water resource and extreme climatic events could affect greatly to production, even drive the farmers to profit loss. More remarkably, with different farming scales, the degree of impacts are likely different.

Table 9: Degree of impacts of climate variability on aquaculture production and output

Scale of farms / Climate variability	Small-scale farms	Medium-scale farms	Large-scale farms
Increasing temperature	+++	++	+
Decreasing rainfall	+	++	+++
Floods/ Heavy rainfall	+++	++	++
Extreme hot temperature	+++	++	+
Extreme cold temperature	+++	++	+

Source: In-depth interviews with farmers (Huong Ngoc Nguyen, 2015)

(Note: +++: High degree, ++: Medium degree, +: Low degree)

Table 9 shows that small-scale farms located in Dong My commune impact from changes in temperature variability with high degree. This is largely because the land areas of those farms are relatively small for fish to adjust in increasing temperature and extreme hot or cold temperature. On the other hand, due to intensive aquaculture systems, those farms need to raise various fish species with high density in order to maximum the productivity. This rises higher risks for small-scale farms to response to the irregular changes in temperature. In contrary, large-scale farms less affect from changes in temperature but high level impacts from lack of rainfall. This can be explained due to lack of alternative water resource, which leads to water stress for those farming scales. More remarkable, the extreme climatic events especially floods have high degree impacts to small farming scale and medium level to medium and large farming scales.

4.1.1. Impacts of Changes in Temperature Variability on Aquaculture Production

The section investigates the way changes in temperature variability impinge on the aquaculture systems based on the perceptions of farmers analyzed in the previous chapter. Major negative impacts which farmers undergo due to increasing summer temperature trend include reducing the productivity and escalate the operation costs for farmers, which results in the decrease of their profit and income. In contrast, ascending winter temperature likely brings the opportunities for fish farmers, especially at small scale, to increase productivity and output with particular fish species.

Increasing Disease to Fish Species

On one hand, while temperature rises up, the amount of oxygen in water would tend to decline, especially at nights *(FF#1, 1st June, 2015).* It can be explained by excessive consumption of water vegetables or process of distributing and combining of organic substances. In the situation, the fishes are prone to death due to lack of oxygen. More considerable, provided that the weather keeps being hot and sunny in a long period, freshwater source would become exhausted and increase the level of heating of water in ponds or farms *(FF#15, 10th June, 2015)*. On the other hand, the changes in temperature likely produce the advantageous environment for the appearance of epidemic diseases such as Vibrato, MBV, HPV, BP, etc. to fish species. The highly rising temperature lowers the resistance of fish as well as worsens the water environment in farms, which turns to be favorable for development of harmful microbes. Specially, wastewater the farmers mostly use for their production is concerned to be poorer, in combination with increasing temperature in hot season would cause the mass death of fishes in communes.

> "Every June or July from 2011 to 2014, my farm lost at least 5-10 tons of fish because of both low level of oxygen in water and increasing disease in fish. The reasons behind I think due to the polluted in wastewater and the weather is getting hotter"
>
> *(FF#7, 4th June, 2015)*

Impacts to Productivity and Income

As mentioned above, rising temperature in hot season impacts negatively on productivity as well as income of farmers, mostly small-scale farmers whose farm areas are under 2 ha.

"I have practiced fingerlings production as fish culture system in my 0.43 ha farm since 2009. My average annual profit is about 40-50 million VND (US$ 2,000-2,500) with average yield of 5 tons. However, in recent 3 years, high temperature in May or June often results in decrease water quality and increase the disease in fish. Especially, in 2013, I lost about 10 million VND (US$ 500) because of death of fishes, which was big amount to my family with 4 people."

(FF#2, 2nd June, 2015)

As the increasing number of hot days, Tilapia is mostly prone to die amongst different type of fishes. Although Tilapia is considered to be suitable to hot temperature in the range of 13.5°C - 33°C naturally, this species is also sensitive to the extreme hot temperature (around 39°C-41°C). Moreover, because of its high value in productivity with average yield of 30 tons/ha, in Dong My and Tu Hiep commune, interviewed farmers tends to raise higher volume of tilapia comparing to other type of fishes. Besides, farmers also utilize commercial feeds for their farms to increase the growth of fishes. Thus, rising temperature along with intensify the volume and growth of tilapia leads to decline the resistance of this type of fish and prone to death, which creates loss in productivity for farmers. Considerably, Tilapia becomes popular food products among middle and low income households in peri-urban as well as urban areas. That means loss of Tilapia affects significantly not only to income of farmers but also to domestic market.

In the past, some farmers practiced shrimp farming in Dong My commune but shrimp is concerned as more sensitive than fishes. While temperature changes to be higher in the long time, farmers experienced a great amount of loss in productivity then turns to reduce their income.

"Ten years ago, while the weather and temperature is stable, I raised shrimp for 6 years from 2006 to 2012 then I had to change to fish production since 2005. It is because shrimp is very sensitive to the weather such as too hot, too cold or even just storms far away. I lost 50 million VND (US$ 2,500) of total income of around 110 million VND (US$ 5,500) in 2010 because of extreme hot."

(FF#6, 4th June, 2015)

Contrary, in the cold season, the changes in winter temperature trend impacts positively to the farmers. While winter temperature is perceived to become warmer in recent two years 2014 and 2015, some farmers could earn mostly income from raising Colossoma because of its high economic value. However, because of the income loss in hot season as the large volume of Tilapia die, only a few farmers increase their total annual income while others are likely earn equivalent to other normal years.

Impacts to Operational Costs

The rising temperature in both hot and cold season makes farmers increase the operational costs, especially to small-scale farmers while they need to use paddle-wheel aerators (Photo 1) to inject dissolved oxygen and harmonize the water environment.

Photo 1: Paddlewheel aerators in a small-scale farm (Dong My commune)

Source: Field survey (Huong Ngoc Nguyen, 2015)

In addition, those farmers also used to pump ground water into their farms to make the water temperature balance by pumping machines (Photo 2).

> "In recent three years, electricity cost in my nearly 1 ha farm increased from about 3 million VND (US$ 150) to 5 million VND (US$ 250) per month because I need to use pumping machine frequently both in hot and cold season to ensure the water temperature balance. This decreased our profit as increase the total expenditure in production."

(FF#8, 5th June, 2015)

Photo 2: Pumping machine in a small-scale farm (Dong My commune)

Source: Field survey (Huong Ngoc Nguyen, 2015)

Overall, the changes in temperature variability are perceived to affect both positive and negative to the production and output in two communes. Positive impacts include escalating productivity or yield which leads to increase income in favor of rising temperature in winter or cold season. Besides, negative impacts are evaluated more significantly, especially to small-scale farmers. In particular, farmers could affect from the rising high temperature in hot season. Increasing disease in fishes which turns to decline productivity in combination with escalating operational costs, thus leads to reduce income of farmers.

4.1.2. Impacts of Changes in Rainfall Variability on Aquaculture Production

Based on the perceptions of farmers about the changes in rainfall variability, as the total amount of annual rainfall tends to decrease, this would affect significantly and negatively to large-scale and medium-scale farms which mainly rely on rain water as one of key water sources for production. Those farmers often use rain water as an alternative water source to refill their fish farms after they pump out water for harvesting. Most farms use water from irrigation canal as the main water source which connects to urban wastewater systems. Unlike the medium-scale and large-scale farms, most of small-scale farms could utilize another water source as groundwater by pumping directly into their farm. However, due to large size of farm area, medium-scale farms with over area of 5 ha to 10 ha and large-scale farms with over area of 10 ha could not apply that practice. Instead, those farmers need to rely on rain water to reduce the occurrence of pollution in irrigation water (wastewater). Farmers perceived that since the amount of rain become less year by year, especially monsoon rainfall in rainy season, the water in their farms begun more polluted without rain. Worse, quite number of farmers forced to reuse the wastewater from irrigation canal many times after harvests, which likely caused the increase in fish diseases.

"My 10.8 ha farm uses only rain water for fish only system because of far from irrigation canal. In recent 3 years, the amount and frequency of rainfall tends to decrease, especially in 2014, thus I need to reserve rain water to another pond to reuse again and again. Lack of rainfall also slows the growth of fishes and decreases my farm's productivity."

(FF#9, 6th June, 2015)

Furthermore, less rainfall combining with increase temperature which creates occurrence of dry spell was recognized to be ascending. This leads to increase the operational cost of medium-scale and large-scale farms in pumping water from irrigation canal into their ponds after harvests.

"My farm has width of 19.8 ha and depth of 2.5m with fish only system using rain water and wastewater as water sources. In recent 5 years, in hot season with less amount of rainfall, usually need to rent pumping machines with capacity of 1000m3 from Irrigation Management Company to pump irrigation water into my farm. The price ranges from 40,000 VND (US$ 2) per hour with machine running by electricity to 44,000 VND (US$ 2.2) per hour for a machine running by oil. Usually one month my farm needs to pump 10 times, equal to costs of around US$800-880 monthly or around US$9,600-10,560 annually. In fact, the annual average revenue in my farm is around US$134,000."

(FF#10, 7th June, 2015)

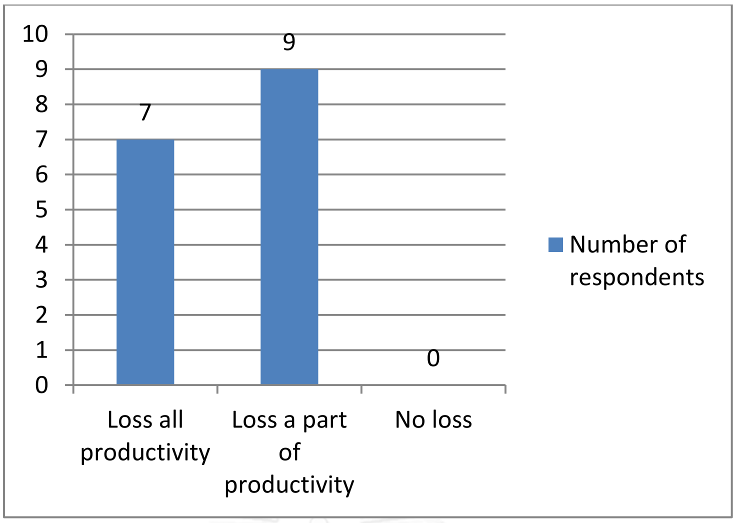
Thus, decreasing amount of rainfall and increasing occurrence dry spells to some extent create the water stress mostly to medium-scale and large-scale farms which depend largely on the rainfall and have no alternative water resource.

4.1.3. Impacts of Extreme Climate Change on Aquaculture Production

Extreme climatic events are most significantly affected to aquaculture production in Dong My and Tu Hiep commune. While perceiving of the impacts, majority of interviewed farmers focused mainly in some extreme events such as flood and cold snap in 2008. The key informant interview with aquaculture specialist in the district has similar perceptions on the flood in 2008 in combination with the cold snap which impacts significantly to the farmers.

During the recorded flooding happened in 2008, all farms affect negatively from the flood with nearly 56.3 percent of the total interviewed farmers lost all their fish, 43.7 percent lost a part of their productivity (Figure 16). However, this type of event would not become high concern in current years because there has been not much rain like that recently.

Figure 16: Impacts of 2008 flood on aquaculture production



Source: Field survey (Huong Ngoc Nguyen, 2015)

In the cold snap or extreme cold event in same year, farmers also experienced the great loss in productivity due to the mass death of fishes, especially Colossoma species. In the cold season with higher intensity of cold days, Colossoma is assessed to be high vulnerable to cold temperature under 10°C for 8-10 days. Because of its high value, even the loss of this type of products clearly caused the decline in farmer’s income. In 2008, farmers lost from 5 to 20 tons of Colossoma equal to 20 million VND (US$1,000) of total annual income 75 million VND (US$3,750) to 200 million VND (US$10,000) of total annual income 500 million VND (US$25,000) because of extreme cold weather. Besides, some farmers decided to sell the Colossoma right before the cold season to reduce the risk of fluctuated weather while the fishes are still small. This leads to decline the productivity and therefore their income.

4.2. Adaptation to Climate Change

Second part of the chapter explores the coping and adaptation practices of fish farmers in Dong My and Tu Hiep communes to understand how farmers response to the impacts of climate change in short-term and long-term. As studied in literature review, coping actions aims to response to immediate dangers and overcome severe damage, which can be considered as short-term and temporary actions. Besides, adaptive strategies refer to long-term actions whose purpose to prevent or reduce current and future damage of climate change events, thus overall aim turns to sustainability (IPCC, 2001; Smit & Wandel, 2006; Smithers & Smit, 1997). Overall, Table 10 illustrates various ways which interviewed farmers at different farming scales in two communes applied to cope or adapt to impacts of changes in climate variability, namely adjusting the farming practices, livelihood diversification, enhancing social capital, risk management or improving knowledge. Details about those adaptive strategies would be explained in the following section.

Table 10: List of adaptive strategies applied by different farming scales

No.	**Group**	**Adaptive strategies**	**Small-scale farms**	**Medium-scale farms**	**Large-scale farms**
1	Adjusting the Aquaculture Farming Practices	Adjusting nutrition or feeding for fishes	x	x	x
		Changing water environment in ponds/ farms	x	x	x
		Buy fish species relevant to seasons	x	x	
		Upgrading dykes of ponds	x	x	
2	Livelihood Diversification	Find part-time job	x	x	
3	Risk management	Early harvesting	x		
4	Enhancing the social capital		x		
5	Knowledge improvement	Update regularly weather forecast information	x	x	x

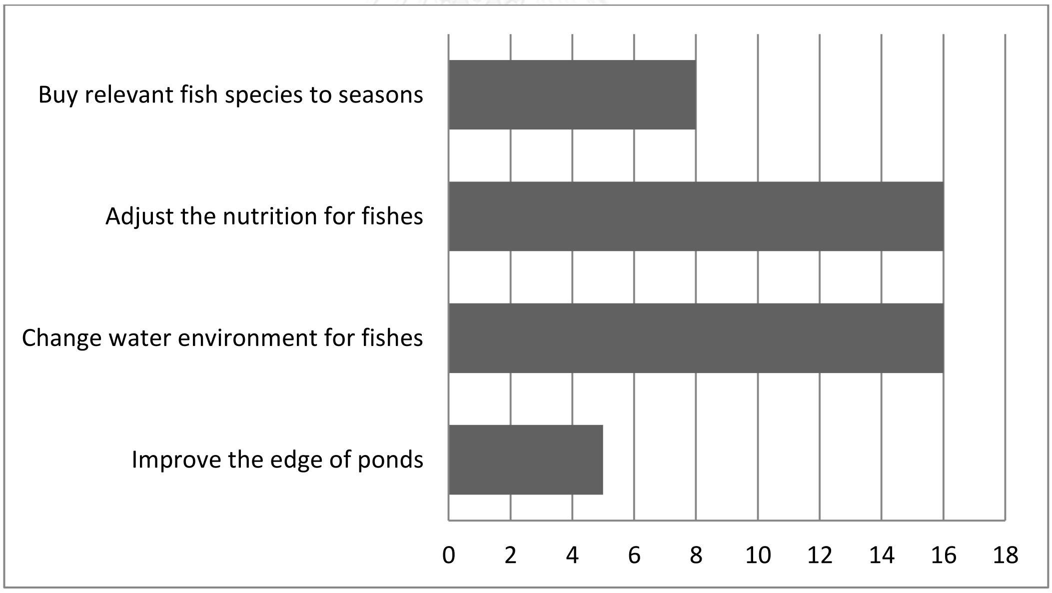
		Improve knowledge in aquaculture techniques	x	x	

Source: In-depth interviews with farmers (Huong Ngoc Nguyen, 2015)

4.2.1. Adjusting the Aquaculture Farming Practices

Figure 17 illustrates the techniques farmers applied to modify their farming practices to cope and adapt to changes in climate variability. Clearly, the top three practices which most farmers exercise include adjusting the nutrition or feeding for fishes; enhancing water environment for ponds or farms; and buy fish species relevant to seasons. In addition, interviewed farmers also use other strategies to modify their farming practices such as improving the dykes of ponds.

Figure 17: Adjustment in aqua-farming practices



Source: Field survey (Huong Ngoc Nguyen, 2015)

Adjusting nutrition or feeding for fishes

As analyzed in the first part of the chapter, in the hot temperature combining with likely polluted wastewater in ponds, fish are in danger of death due to not only lack of oxygen in water levels but also commercial supplementary feeds for exaggerating the productivity. In order to cope with this impact, 100% interviewed farmers adjust the nutrition for fish. On one hand, they decrease the amount of feeds while the temperature rises up because fishes which get feed too much are more sensitive to lower oxygen level and at risk to death.

On the other hand, most farmers modify the type of feeds supplied for fish in order to increase the resistance level of fish to changes in temperature. In addition to commercial formulated feeds (Photo 3), small-scale farmers in Dong My commune often use additional feeds as duckweed *(lemnoideae)* (Photo 4)which also attribute to clean water. However, the additional feeds would increase the production costs for farmers. For example, while the price for formulated feeds is about 12,000 VND (US$ 0.6) per kg, price for duckweed is around 30,000 VND (US$ 1.5) per kg.

Photo 3: Commercial formulated feeds (Tu Hiep commune)

Source: Field survey (Huong Ngoc Nguyen, 2015)

Photo 4: Duckweed used as additional feeds for fishes (Dong My commune)

Source: Field survey (Huong Ngoc Nguyen, 2015)

Furthermore, due to changes in weather, especially in extreme events such as heat waves or cold snaps, farmers need to adjust their time schedule to feed the fish in order to keep fish away from increasing diseases and prone to die. For instance, in hot season with prolonged hot days, most farmers feed fish at 8AM instead of 10AM in the morning because the temperature is lower in earlier morning, which reduces the risk for fish while feeding.

Changing water environment in ponds/ farms

In order to response to the changes in temperature variability, all farmers have applied the practice of changing water environment in ponds or farms. For small-scale farmers, they operate paddle-wheel aerators in excessive and continuous hot days or extreme cold days in order to balance temperature and oxygen level in water, which helps fish species keep in their own adaptable temperature range. Besides, those farmers also pump additional groundwater into their farms in order to increase the level of water and decline the rising temperature in water at deep level. For medium-scale and large-scale farmers, because of large farm size, they only use boats to go around the farms three times per day so that water could absorb oxygen with movements. Supplementary, most farmers make use of aluminum sulfate to reduce the polluted in water by settling down the waste, thus increase the water source before moving fish back to the ponds.

Buy fish species relevant to seasons

Based on the experience and lessons learnt from the loss of production due to abnormal changes in temperature variability, 50% of interviewed farmers found out the types of fish species relevant to each seasons. In hot season, those farmers often reduce the amount of high-value Tilapia species due to its sensitive to excessive hot weather and increase other type of fishes such as common carp, silver carp, mud carp, etc. In cold season, Colossoma could be declined the amount in rising while also increasing other type of fishes. Noticeable, other types of fish species were chosen based on their suitable not only in climate but also to market also. Thus, in spite of reducing raising Tilapia or Colossoma makes total profit likely declined, some farmers still got higher income comparing to the previous years they lost productivity.

Upgrading dykes of ponds

In total of 16 interviewees, 5 of them (equal to 31.3%) including 4 small-scale farmers in Dong My commune and 1 medium-scale farmer in Tu Hiep commune applied the solution of upgrading dykes of ponds in order to adapt to the extreme events such as floods which cause by heavy rain. While small-scale farmers upgrade their dykes by concreting dykes high about one meter above water surface, the farmer having medium-scale farm upgrade dykes to adapt with the flood by piling up the ground every year. Moreover, the farmer also created an adjustable and flexible fence by fishnet so that fishes can maintain well in the ponds while heavy rain or floods happen.

> "In rainy season, I often need to rent labor and machine to pile up the ground with estimated cost around 10,000 million VND (US$ 500) per time and around 3 times per year."
>
> *(FF#12, 9th June 2015)*

Noticeably, although some medium-scale and large-scale farmers acknowledge the importance of dykes, they do not want to invest in building the dykes because of short-term land lease contract (5 years). The insecurity in land tenure, particularly farmers only have control over their land for short period has been addressed to be serious problem farmers have confronted because it related to land development costs and relatively high investment such as dyke improvements (Rigg & Salamanca, 2005).

4.2.2. Livelihood Diversification

In fish farming households, fish aquaculture is considered as major livelihoods whose income contributes the most for households' income. Due to the uncertainty in changing climate and reduction in water quality, some households need to diversify their income source by looking for additional permanent or seasonal jobs. Among interviewed farmers, 4 of small-scale farmers in Dong My commune need to work temporary jobs in the area such as construction and other labor jobs, especially, in cold season when they forced to decline production in order to reduce risk of extreme cold weather. Further, it is also because major harvest time belongs to hot and rainy season so that farmers have more free time in cold season to look for other jobs. However, those temporary jobs only contribute a little to households' income.

More noticeable, to some households at small-scale farms which had both male and female working full-time at the farm, the wives now need to spend part-time to buy vegetables in Yen So wholesale market near Dong My commune and sell at markets in urban center of Hanoi because the income from aquaculture did not be enough for whole family with 4 people *(FF#2, 2nd June, 2015).* It could be noticed the livelihood diversification strategy has mostly applied by small-scale farmers because of larger impacts and vulnerability to changes in climate than in medium-scale and large-scale farms.

Figure 20 demonstrates the changing role in main income generator before and after 2008 with the implications from the huge impacts of flood and cold snaps in that year. Prior to 2008, 81.3% interviewed households said that male is the main income generator for the family while 18.7% are female. After 2008, the number of male who generates main income decreases to 68.8% while the number of female as main generator increases to 31.2%. This could be explained by the pressure of production loss after the flood and excessive cold in male farmers to maintain the income of the family.

Figure 18: Changes in main income generator before and after 2008

Source: Field survey (Huong Ngoc Nguyen, 2015)

4.2.3. Risk management

In general, farmers mostly base on their own experience to manage risks from changes in climate variability. For instance, in cold season, on one hand, a few farmers still maintain the same amount of Colossoma species due to its higher economic value comparing to other species. On the other hand, they have applied early harvesting as another strategy to prepare for future cold weather.

> "Before winter, around at the end of November, I often harvest 80% of total Colossoma yield although the size of fish at that time is still small. I accept risk with the rest (20%) if the extreme cold weather happens, which often leads to loss of production. However, if the winter is not fluctuated and abnormal, I would likely achieve a significant profit from this."
>
> *(FF#15, 10th June, 2015)*

4.2.4. Enhancing the social capital

Interestingly, in Dong My commune, farmers often cooperate together as informal network in production in order to reduce costs. For instance, interviewed farmers pointed out that they often pump irrigation water at the same time to save operational costs. These community collective actions can be explained that Dong My commune belongs to aquaculture zoning plan of the district so farmers easier to cooperate together. However, the collective actions have been evaluated as minor. In contrary, in Tu Hiep commune, farmers mostly base on their own experience to adapt with the situation without joining or forming any groups.

4.2.5. Knowledge improvement

Update regularly weather forecast information

Since the weather is abnormal these days, the farmers update the weather information frequently with two or three times per day, mostly via commune radio or television. Some used internet through mobile phone to update the weather. The farmers adapt the weather changes based on their own experience since the weather information from the government is general information and also not too specific for aquaculture. For example, if they find the fin of silver carp fish appeared on the water surface, it can be assumed that the weather for next day would be cold. If the temperature is extreme hot, farmers modify the density of fish in the ponds by reducing the input number of fish into the pond after harvest.

In terms of forecasting services, the aquaculture specialist from the district mentioned that the government informs farmers early every year before the hot or cold season start. The information has been disseminated via commune radio or direct visit to farms. Moreover, the district level could receive urgent information quickly, e.g. storms or disasters, through the online information system connected between Hanoi City People’s Committee to district and commune levels.

Improve knowledge in aquaculture techniques

Most of interviewed farmers in Dong My commune access to aquaculture trainings organized by District Agriculture Extension center in order to improve techniques. The interviewed key informant confirmed that the trainings about the techniques to cope with the hot or cold temperature were usually done at one commune then invited other farmers from different communes to participate. Farmers would learn about new techniques in aquaculture farming from experts through demonstrations, training and propaganda.

> "I often joined trainings from District Agriculture Extension center. I think the quality of training is quite good as we can learn the latest techniques and update more useful knowledge for our practices. However, the training has been organized only one or two times per year so the information was not so updated. Because the weather changes very quickly, thus we prefer to learn from each other or ask the "technical consultant" in the commune. He practices seed production and have a lot of knowledge on species we should raise in fluctuated or extreme climate."
>
> *(FF#8, 5th June, 2015)*

Oppositely, in Tu Hiep commune, farmers did not often participate on aquaculture trainings of District Agriculture Extension center and seldom join meetings of Farmers Union or Agriculture Cooperative. This could be explained by the distance between farms is spatial and because most of farmers in Tu Hiep commune have the aquaculture farming experience from 20-30 years so that their perceptions on changes, impacts and adaptive strategies mostly based on their personal experience. Furthermore, they perceived that training quality does not effective and meet their demand due to the difference between academic and reality.

4.3. Community and Individual Adaptive Capacity

Last section of the chapter discusses the community and individual households adaptive capacity to explore the potential and ability of community and fish farmers to adjust to changes in climate variability and its impact. The adaptive capacity would be analyzed based on community and farmers' resources including physical capital, financial capital, social capital, human resources and natural resources. Overall, the section aims to examine how adaptive capacity affects to their adaptive strategies to climate variability and impacts.

4.3.1. Physical capital

On one hand, interviewed farmers in both communes are evaluated as having the advantage in adequate infrastructure such as road, electricity which are the critical factors for developing aquaculture. This can be explained by the economic development in the district as well as in the communes since the district becomes the periphery of urban Hanoi. On the other hand, irrigation systems in both communes are assessed to be poor. This seriously affects to fish farmers because water quality also plays an important role in fish culture systems. In Dong My commune, farmers perceived that there was the water system for aquaculture which built separate with agriculture irrigation system in 2007 and connected to the Red River. However, since that time, only one interviewed farmer in the commune confirmed to use that water in trial time for short-time. Others informed that they have never accessed to that water for their aquaculture production before. In Tu Hiep commune, there was no separate irrigation system from agriculture so that farmers have no alternative water source except from wastewater and rain water which is perceived as getting less years by years.

Thus, it could be concluded that although farmers in both communes have favorable conditions in road and electricity infrastructure, they are confronting the serious problem about water stress because of dependency on wastewater and rain water. While wastewater turns to reduce quality due to urban expansion and industry activities, rain water also has tendency to decline because of fluctuated changes in climate variability such as hot temperature combing with less rainfall which turns to dry spells. Overall, water stress likely reduces the adaptive capacity of communes as well as farmers themselves in adapting to climate change in the future.

4.3.2. Financial capital

Regards to financial capital, fish farmers in both communes were assessed to be in the middle income with the annual income ranging from at least 30 million VND (US$ 1,500) to 500 million VND (US$ 25,000). Increase income leads to higher living standard in the communes. Most farmers were observed to have good facilities at their workplace or houses such as television, motorbike or even air condition. This implies that higher living standards likely help farmers cope or adapt with the change in climate easier. For example, farmers can access to weather information regularly through television or they can reduce the difficulty in working condition during hot days due to using air condition.

Further, most farmers can access to credit from Agriculture and Rural Development Bank or Agricultural Extension Center in order to buy feed for fish, buy fish species, invest in working facilities such as fishnet, boat, pumping machines, etc. With small-scale farmers in Dong My commune, they often borrow the loan with subsidized interest rate from Agricultural Extension Center with 4-5% per year. However, those farmers perceived total amount of loan from this source is small or they also do not want to take risk since their income is uncertainty. With the large-scale farmers in Tu Hiep commune, they have to invest high capital in their farms, thus they do not often borrow loans because of high risk. Noticeable, after long time operating the farms, some have enough capital to reinvest in the farm also.

In term of the financial support to the impacts of climate variability to farmers in the district, farmers mentioned the only cash support from the District People's Committee for the damage of flood in 2008. Many of them confirmed that the supported amount covered about 10% of their loss or was enough only to cover fish seeds cost. According to the key informant, the Hanoi City Government provided the fish farmers who were the victims of the flood in 2008, about 15 million VND (US$ 750) per ha with the additional support from the District with the amount of 5 million VND (US$ 250) per ha. The support money was given to the farmers who lost more than a half or all the production.

Overall, most of fish farmers in both communes have adequate financial capital which might increase their adaptive capacity in responding to changes in climate variability and its impacts.

4.3.3. Social capital

As mentioned in literature review in second chapter, social capital mentions to various factors such as strong institutions, transparent decision-making systems, formal and informal networks that promote collective action.

In terms of institutions related to aquaculture, in the district level, Thanh Tri District People's Committee under the Hanoi City People's Committee has responsibilities to evaluate and approve plans which Economic and Rural Development Unit and Extension stations submit to. District People's Committee and Hanoi Agriculture Extension Center are both conducted the progress of the city aquaculture development. District People's Committee conducts the progress of programs and plans of the Commune People's Committee. Economic and Rural Development Unit has responsibilities in economic development of the district including agriculture, forestry, aquaculture and irrigation. This unit together with Agriculture extension center guide communes in implementing agriculture and aquaculture development plans. District Extension Unit is responsible for supporting farmers access to new knowledge or techniques related to aquaculture or distribute compensation, etc. In commune level, Commune People's Committee which is under District People's Committee has Economic Unit and Extension Unit. Deputy Chairman of Commune has responsibility in agriculture and aquaculture management. Commune extension staff is responsible for supporting farmers in aquaculture production. Furthermore, there are a several mass organizations as formal networks in each commune, for example Farmer Union, Women Union, Agriculture Cooperative, etc. At households or individual level, households work directly with Commune People's Committee in signing land lease contract or District Extension station about technique trainings advice. Besides, individual farmers could ask advice from Research Institute for Aquaculture No.1 which has responsibilities in research high quality seed, technical and consultants for district or commune staff or for farmers through extension training programs. While farmers in Dong My commune often join the meetings or trainings organized by the Extension Unit or Agriculture Cooperative, farmers in Tu Hiep commune do not because they perceived that it is more relevant for them to apply their experience than academic techniques in the trainings.

Regards to informal network, only in the case of Dong My commune, as considered as an aquaculture zones, farms often located close to each other which creates the favorable condition for farmers gathering and forming their network. However, the network promoting collective action in the commune is perceived as informal and limited as they only grouped together to share the cost of pumping to reduce expenditure in their farms. Currently, large number of farmers adapt to changes in climate variability as autonomous strategies based on their personal experience.

In general, while social capital in Dong My commune likely brings advantages for farmers in the communes, it seems to be less helpful for large-scale farmers in Tu Hiep commune.

4.3.4. Human capital

In terms of skills and knowledge, both interviewed farmers in the communes have profound understanding and experience about the aquaculture production because they operate fish farming for long time ranging from 10 years to 30 years. This implies that most farmers have relevant expertise knowledge to adapt with changes in climate. However, farmers face challenges in early knowing those changes because of its uncertainty. This might reduce their adaptive capacity in responding to the changes.

Regards to access to extension service and transfer of technology, small-scale fish farmers mentioned that the quality of the trainings was good and they could learn the helpful knowledge from trainings. However, because of too less in number of trainings with only one or two times per year, the techniques were often out of date. Large scale farmers mentioned the knowledge in the training did not match with the reality.

4.3.5. Natural capital

To aquaculture production, natural capital such as land, water or biodiversity are critically important. As mentioned before, water stress impacts negative to farmers' adaptive capacity. The reason includes the lack of rainfall in combination with decreasing water quality in both communes. The roots of the problem mainly lie on the significant influence of urbanization and weak institutional arrangements in pollution control. Urban growth leads to increase wastewater amount and reduce land use for aquaculture turns farmers to intensify their farms to maximize the yields. Another challenge for the fish farmers, especially in Tu Hiep commune is land tenure while their land lease contract is short-term which creates difficulty for them in making concrete decisions due to high capital investment.

Further, the policy for aquaculture development in the District in the future prioritizes investing in aquaculture zones including Dong My commune and replacing aquaculture land in other areas including Tu Hiep commune for urban planning. The interviewed key informant mentioned that according to the policy from Hanoi City Government about aquaculture zones, small-scale farms would be gathered into larger farms which need to bigger than 2.1 ha. Thus, the number of fish farmers in Dong My commune might likely decrease. Besides, those fish farms changed land use for urban expansion would be turn into ecological lake to contain the waste water from the city which is likely to harmonize the weather in the city. This means the farmers which majorly at large-scale in Tu Hiep commune would affect most and are at risk of loss livelihoods in the future.

CHAPTER V
CONCLUSION AND RECOMMENDATION

The last chapter of the research concludes the findings and analyses in previous chapters and highlights the main theme and key messages of the study. Based on the conclusion, the chapter gives recommendation for policy makers

5.1. Conclusions

In conclusion, the research focuses on the perceptions of fish farmers at different farming scales of climate variability in the areas and examines how farmer's perceptions of causes and impacts of climate variability influence their adaptive responses. Moreover, by analyzing and discussing on adaptive capacity of those farmers, the study points out the challenges as well as opportunities for farmers in adapting to changes in climate variability and its impact.

The results of the research showed that fish farmers in the studied communes have an increasing concern about local climate variability. They perceived changes in temperature, rainfall variability and frequency and intensity of extreme climatic events based on their memory, direct and current experience with climate factors affected most to their aquaculture production. While temperature was perceived with increasing trend, rainfall variability was received the opinion of decreasing trend. In addition, floods or heavy rainfall was highlighted to decrease, other extreme events such as heat waves and cold snaps were considered to be upward trend. However, the perceptions about climate variability of fish farmers in two communes mostly based on the short-time period for about recent 5 to 10 years, not long-term changes.

Following the perspectives on changes of climate variability, farmers at different farming scales perceived impacts of those changes to aquaculture production and output. It has been found out that the degree of impacts are likely different with different farming scales. While small-scale farms impact from changes in temperature variability with high degree, medium-scale and large-scale farms high level impacts from lack of rainfall. Besides, the extreme climatic events especially floods have high degree impacts to small farming scale and medium level to medium and large farming scales. Overall, amongst farming scales, small-scale farms affect most from the changes in climate variability and become the most vulnerable to those changes comparing to others scales. More notably, impacts from changes in climate variability would affect both negatively and positively to farmers in the communes, largely direct on the productivity and indirectly to households' income and their livelihoods. Furthermore, those consequences in the study area are caused by not only climate factors such as temperature, rainfall or extreme events but also non-climate factors, particularly external stresses from urban expansion and industrial activities. The increasing pressure from urbanization leads to decrease water quality and land use for aquaculture, which exacerbate the impacts of changing climate.

In order to response to changes in climate and its impacts, fish farmers in Dong My and Tu Hiep communes pointed out their adaptive strategies in short-term and long-term. Interviewed farmers in two communes have various ways to cope or adapt to those impacts including adjusting the farming practices, livelihood diversification, enhancing social capital, risk management or improving knowledge. In which, small-scale farmers need more strategies and practices to adapt with the changes in climate variability in combination with the decreasing environmental quality than other scales. It could be explained by the significant and high level impacts small-scale farms affect from.

Further, the research investigates the community and individual households adaptive capacity to examine how adaptive capacity affects to their adaptive strategies to climate variability and its impacts. The adaptive capacity as the potential and ability of community and fish farmers to adjust to changes in climate was analyzed based on community and farmers' resources including physical capital, financial capital, social capital, human resources and natural resources. In terms of physical capital, while farmers in both communes have favorable conditions in road and electricity infrastructure, water stress because of inadequate water system likely reduces the adaptive capacity of communes as well as farmers themselves in adapting to climate change in the future. However, most of fish farmers in both communes have adequate financial capital and access to credit which might increase their adaptive capacity in responding to changing climate. Besides, while social capital in Dong My commune likely brings advantages for farmers in the communes, it seems to be less helpful for large-scale farmers in Tu Hiep commune. In terms of skills and experience, both interviewed farmers in the communes extensive experience around 10 years to 30 years about the aquaculture production, thus enhance adaptive capacity of farmers. This also explains why most of farmers adapt to changes in climate variability as autonomous strategies based on their personal experience. Regards to access to extension services, the infrequency of the trainings to transfer techniques and practices in aquaculture production could likely reduce adaptive capacity of farmers, especially at small-scale farms. More considerably, medium-scale and large-scale farms have confronted with the problem of land insecurity with short-term land lease contract, which probably reduce their adaptive capacity to changes in climate variability. Under the pressure of urbanization, those farmers are expected to affect significantly from policies in aquaculture development in the district with reducing aquaculture land use for urban expansion.

5.2. Recommendations

The recommendation mainly based on the farmers' perspectives on climate variability and perceived impacts as well as adaptive strategies farmers have applied to response to those changes. Besides, with ultimate goal of livelihoods sustainability, some key suggestions would be discussed to enhance their adaptive capacity to response to changes in climate variability and its impacts.

First of all, although a large number of interviewed farmers have not heard about the term "climate change", their perceptions about the changes in climate showed that farmers acknowledge quite comprehensive about the changes in environment surrounding them and affect to their livelihoods. Thus, it would be recommended that the most effective ways to raise awareness to farmers are through local communication channel such as commune radios and with easy language.

Second, water stress issue should be addressed immediately because of decreasing rainfall and increasing polluted water. In particular, since Dong My commune had the separate water system for aquaculture but have not operated effectively yet, the district government should prioritize to repair, maintain and operate the system, thus solve one of the biggest challenges for the farmers in the commune.

Third, land tenure issue also should be discussed and negotiated between the government and farmers in Tu Hiep commune so that the period of land lease contract could be expand which supports farmers have more confident in making concrete decisions such as investing in dyke improvement. Moreover, as aquaculture land tends to decrease and its production limits to specific communes in the district with aquaculture zoning, the livelihood support strategies should be planned for farmers who would lose their land for urban planning and have no alternative income sources.

Fourth, insurance schemes for aquaculture should be developed as most of farmers expected to have aquaculture insurance in order to reduce risk in aquaculture production.

Last but not least, the ecosystem approach to aquaculture (EAA) proposed in some countries should be concerned by policy makers across sectors. The approach proposes to integrate aquaculture with other sectors such as agriculture or urban development which share, affect and influence common resources including land, water, etc. It could be implemented at different spatial scales such as the farm; the aquaculture zone, water-body or watershed where the activity operates; and the global scale (Soto et al., 2008). Because of its typical characteristic of peri-urban areas with mixed and complex activities, policy makers of Thanh Tri District as well as Hanoi City Government could consider this comprehensive approach to manage aquaculture as well as promote sustainability of socio-ecological system.

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APPENDIX

Annex 1: List of interviewed farmers in Dong My and Tu Hiep commune

Code	Date of interview	Farm area (m2)	Farm area (ha)	Culture systems	Commune	Gender	Age	Scale*
FF#1	1st June, 2015	3,600	0.36	Integrated system	Dong My	Male	61	S
FF#2	*2nd June, 2015*	4,320	0.43	Fingerlings	Dong My	Male	52	S
FF#3	*2nd June, 2015*	6,840	0.68	Fingerlings	Dong My	Male	60	S
FF#4	*3rd June, 2015*	10,000	1	Integrated system	Dong My	Male	35	S
FF#5	*3rd June, 2015*	20,000	2	Fingerlings	Dong My	Male	35	S
FF#6	*4th June, 2015*	20,000	2	Fish only	Dong My	Male	55	S
FF#7	*4th June, 2015*	8,600	0.86	Fingerlings	Dong My	Male	50	S
FF#8	*5th June, 2015*	9,300	0.93	Fish only	Dong My	Male	55	S
FF#9	6th June, 2015	108,000	10.8	Fish only	Tu Hiep	Male	32	L
FF#10	7th June, 2015	198,000	19.8	Fish only	Tu Hiep	Male	52	L
FF#11	*8th June, 2015*	378,000	37.8	Rice-cum-fish	Tu Hiep	Male	53	L
FF#12	9th June, 2015	70,000	7	Rice-cum-fish	Tu Hiep	Male	61	M
FF#13	9th June, 2015	252,000	25.2	Fish only	Tu Hiep	Male	58	L
FF#14	*10th June, 2015*	44,000	4.4	Integrated system	Dong My	Male	45	M
FF#15	10th June, 2015	35,000	3.5	Fish only	Tu Hiep	Male	55	M
FF#16	11th June, 2015	28,000	2.8	Fingerlings	Dong My	Male	42	M

*Small-scale = S; Medium-scale = M; Large-scale = L

VITA

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