Floods in Southeast Asia:
A Household Welfare Priority

Dissertation zur Erlangung des wirtschaftswissenschaftlichen Doktorgrades der Wirtschaftswissenschaftlichen Fakultät der Universität Göttingen

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Acknowledgments

Foreword

I call myself "the daughter of water": where I was born, the village is surrounded by rivers. My childhood was tied with water, playing with water, drifting in water several times; but the benevolent river gave me back to life. In the rainy season, when water from the upstream to the rivers was rising into the house, my parents ordered me to just sit on the bed stuffed up with home tools; then I had nothing to do but using a stick to create stories on the water. Suddenly, I wished water should come every day so I would not have to go to school. At that time, I was too small to be aware that I was so much luckier than many people in the central part of Vietnam, where in the flooding season, water rises up to the roofs of houses; for people living in such a situation "the ground becomes their sleeping mat; and the sky becomes their sleeping net".

In November 1999, when I was a fresh student at the Vinh University, that day came when for the first time in my life I experienced a serious flood. Vinh City is located on the banks of the Lam River; in normal days, the river looks poetic and charming as a beautiful lady, but in days of flooding, the river looks like a water monster that can devour villages and city alike. In the past, such a big flood was called "the greatest flood in history". Nowadays, due to climate change, such big floods have been reported more frequently. Anywhere in Vietnam, every year we experience floods. In the North and Centre, floods come with heavy rain and storms, carrying away both people and property. In the South, floods come from the tide; in Ho Chi Minh City, we go to work on streets with water up to our knees. In schools, children have to roll up their trousers to enter the classrooms. In the rented houses of migrant workers, water rises near to their beds.

In difficult times, kindness is revealed and multiplied. We have a saying "The good leaves protect the worn-out leaves; the less worn-out leaves protect the more worn-out leaves". In every corner of our country, we contribute money, collect clothing and foods, and then send donations to heavily affected areas. Every year, in Vietnam in particular, and in Southeast Asia in general, everyone is prepared to cope with floods and to contribute to aid for flood relief.

When I arrived in Göttingen in November 2014, Prof. Sebastian Vollmer asked me to find an interesting and urgent topic to study: immediately I thought of the floods. For me, the impact of floods is not just a topic but also an experience. However, working with flood impacts, I have had to face with a difficulty in collecting flood data. I tried several available flood data sets, but they did not work well with the household data. Finally, I decided to take a huge challenge to extract flood data from satellite images provided by NASA. The combination of a rich household panel data set and external long-term flood data has enable me to study the impacts of floods on households in multi-dimensional aspects.

No matter with how much effort I have tried, the story told in this dissertation can only reflect a small part of reality. Limitations of flood data, of household data, of econometric models only enable me to give estimations of impacts, as a message to the world about the impacts of floods in Southeast Asia. The results cannot reflect the extraordinary efforts of local people to cope with floods, generation to generation living with floods: in difficulties still sustaining their resilience. The results cannot convey the humanity, the kindness of neighbors towards each other when in hardship. Hopefully, we will have more vigorous research on the impacts of floods in the future.

Table of contents

List of Tables

List of Figures

List of Abbreviations

BMI	Body Mass Index for adult
CRED	The Centre for Research on the Epidemiology of Disasters
DFG	The German Research Foundation (Deutsche Forschungsgemeinschaft)
FE	Fixed effects
GIS	Geographical Information Systems
IHS	The inverse hyperbolic sine method
IPCC	The Intergovernmental Panel on Climate Change
MODIS	The Moderate Resolution Imaging Spectroradiometer
MFW	MODIS Flood Water image
MSW	MODIS Surface Water image
OECD	The Organization for Economic Co-operation and Development
OTOP	The One the One Tambon One Product project
P135	The Program 135
PPS	Probability proportional to population size
SD	Standard deviation
SWB	Subjective wellbeing
UNEP/ DEWA/GRID	United Nations Environment Program's global group of environmental information Centre
USC	The Universal health Coverage Scheme
WHO	The World Health Organization
ZBAWHO	WHO measure weight for age 0-5 z score
ZWAWHO	WHO measure BMI for age 5-19 z score

Introduction

Out of all natural disasters, floods are the most common in both developed and developing countries, accounting for approximately 40% of all natural disasters. From 1970 to 2014, the world reported a total of 11,985 natural disaster events, of which 5,139 (or 42.9 per cent) took place in Asia and the Pacific (Figure A1). Floods were the most frequent in the region, accounting for 35% of the total number of such events reported between 1970 and 2014 (Figure A2). Moreover, Southeast Asia is a region that is especially prone to frequent and severe natural disasters (Figure A3).

Figure A.1: Total Occurrences of Natural Disaster Events (1970-2014)
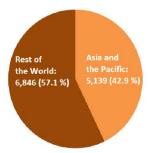
Figure A.2: Occurrences of Natural Disaster Events in Asia and the Pacific by Type (1970 – 2014)	*Figure A.3: Occurrences of Natural Disaster Events in Asia and the Pacific by Sub-region (1970 – 2014)*
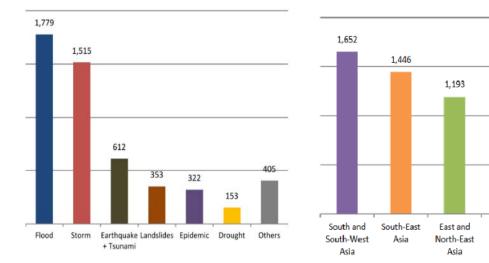
Source for all figures: UNESCAP, ESCAP Statistical Database; and EM-DAT, The OFDA/CRED International Disaster Database – www.emdat.be

In this introduction, I discuss why flooding is a problem in Southeast Asia, and why I argue that flooding warrants priority in the attention given to it, compared to other problems in the area. This is due to the household's welfare impactions that arise as a result of flooding. I go on to state the purpose of this dissertation, which is to provide empirical evidence for the scale and severity of this problem in Southeast Asia.

Floods impact on individuals, households and communities, and have health, economic, social, and environmental consequences. The consequences of floods, both negative and positive, vary greatly depending on the location and extent of flooding, and the vulnerability and value of the natural and constructed environments they affect.

The immediate impacts of flooding include loss of human life, damage to property, destruction of crops, loss of livestock, and deterioration of health conditions owing to waterborne diseases. As communication links and infrastructure such as power plants, roads and bridges are damaged and disrupted, some economic activities may come to a standstill, people are forced to leave their homes and normal life is disrupted.

Similarly, disruption to industry can lead to loss of livelihoods. Damage to infrastructure also causes long-term impacts, such as disruptions to supplies of clean water, wastewater treatment, electricity, transport, communication, education and health care. Loss of livelihoods, reduction in purchasing power and loss of land value in the floodplains can leave households economically vulnerable.

The effects of floods on human health are related directly to the location and topography of the area, as well as human demographics and characteristics of the built environment. Reported flood-related impacts on human health are widespread and complex; floods continue to impact communities unequally and in different ways, with effects ranging from short to long-term, direct and indirect. It is apparent that the most readily identified flood deaths are those that occur acutely from drowning or trauma, such as being hit by objects in fast-flowing waters. Flood-related injuries may occur as individuals attempt to remove themselves, their family, or valued possessions from danger. There is also potential for injuries when people return to their homes and businesses and begin the clean-up operation. In flood conditions, there is potential for increased fecal-oral transmission of disease, especially in areas where the population does not have access to clean water and sanitation. Diseases transmitted by rodents may also increase during heavy rainfall and flooding, because of altered patterns of contact.

Studies of the flood impacts on agriculture have documented the whole picture of negative effects, as agricultural production is heavily influenced by weather and climate. Studies show that floods bring significant damage to agriculture and

aquaculture by destroying crops in rice fields, sweeping away aquaculture products, or ruining fish and shrimp ponds.

Floods are expected to impact household welfare in various ways, ranging from the loss of life, injuries and health effects, to the destruction of assets, and reduced incomes. However, little evidence exists to support the impact of floods on household wellbeing. There has been an overwhelming focus on assessing the physical or tangible impacts of flooding; however, much less is known about the intangible impacts or effects on wellbeing of flooding.

Studies on climate change also show that floods are increasing in Asia and bring many negative effects to human populations, as a result of negative impacts on the agriculture and resulting increases in food prices. The rising cost of living will in turn have an increasing impact on human health, security, livelihoods, and poverty, with the type and magnitude of impact varying across Asia. Researchers and policymakers recognize that, in a context of increasing vulnerability, such changes will lead to increased stress on human and natural systems.

Researchers around the world contribute findings for this field of study from different contexts, different time periods, different methods of welfare measures, as well as using different flood indicators, all depending on the availability of data that researchers can assess. All research findings are necessary to create a global picture of the relationship between floods and household welfare. However, we lack research where the relationship between floods and household welfare is examined in multiple dimensions on the same population over time. This study will contribute such a missing piece to the whole picture available in the literature, by furnishing empirical evidence in relation to Southeast Asia.

This dissertation aims to answer three broad research questions: (1) How do floods impact on households in multi-dimensional concept of welfare: in term of health impacts, agricultural production impacts, income and consumption impacts, and household subjective wellbeing?" (2) "which group of households are more vulnerable to floods?". And (3) "Which channel of insurance mechanism is commonly used and effective in rural households to cope with flood shock?"

The dissertation focuses on floods in Vietnam and Thailand using long-time measurement of household welfare, combined with an external flood indicator, which is a measure of local inundation by using satellite floodwater images provided by NASA, the MODIS Near Real Time Global Flood Water (MFW). These satellite images were constructed using Geographical Information Systems (GIS) and Google Earth to draw neighborhoods of villages. Linking these data sources allows us to estimate the impact of varying flooding intensities on an array of household welfare outcomes in a panel regression setup. The detail describe of the data sources and estimation approaches can be found in Methodology sections.

The range of the effects of flood on health at both individual level and household level are examined in **Chapter 1**. The results show that floods create a burden on human health. Individuals face an increased likelihood of contracting serious disease, experiencing general sick-health, and being underweight if floodwater in their villages is increasing. Floods also cause a financial cost for households with an increased expenditure per capita. The findings from an analysis of coping strategies show a fact that the effects of floods on human health are difficult to cope with; we do not find any effective coping strategy dealing with flood-related health.

The findings in **Chapter 2** show both negative and positive effects of floods on agriculture. While floods increase expenditures and reduce incomes, they can also increase rice productivity. This chapter also sheds light on the concept of vulnerability; suggesting that, a group of people become more vulnerable when we measure outcomes with monetary values, but not if we solely measure outcomes by quantity.

Chapter 3 presents compelling evidence that floods inflict a wide range of negative effects upon household welfare. Flooding reduces household incomes dependent on natural sources, pushing farmers out of the fields to seek extra income from non-agricultural activities. Moreover, floods increase all categories of household consumption. All these results are reaffirmed by the finding of a lower household subjective wellbeing score.

Overall, the findings of this dissertation suggest that the experience of living in villages that are subject to flooding is not a happy one.

There are gaps in the research on flooding which should be addressed, as well as the gaps in understanding how we can reduce the implications of floods. In terms of health impacts, further research needs to be conducted to determine the mental health implications of flooding, little research has been done to examine long–term health implications, even in high-income countries. In term of agriculture impacts, understanding land use change floods, and floods change the land use scale, are challenges and opportunities for future research. The study of household wellbeing implications of flooding and climate change are a relatively juvenile and there are many knowledge gaps in the literature that need to be addressed through further research and exploration.

Überflutungen in Südostasien: Eine Priorität von Haushalts-Wohlfahrt

Die Dissertation beschäftigt sich mit Überflutungen in Vietnam und Thailand und nutzt dabei Langzeit-Messungen von Haushalts-Wohlfahrt sowie einen externen Flut-Indikator, welcher lokale Überflutungen mittels NASA Satellitenbildern – den MODIS Near Real Time Global Flood Water (MFW) – aufweist. Die Verknüpfung dieser Datenquellen ermöglicht es uns, die Auswirkungen unterschiedlicher Überschwemmungsintensitäten auf eine Reihe von Wohlfahrtsergebnissen in Panel-Regressionen zu schätzen.

In Kapitel 1 wird das Spektrum der Auswirkungen von Überflutung auf die Gesundheit sowohl auf individueller Ebene als auch auf Haushaltsebene untersucht. Die Ergebnisse zeigen, dass Hochwasser eine Belastung für die menschliche Gesundheit darstellt. Im Falle von einer Überflutung haben Dorfbewohner eine erhöhte Wahrscheinlichkeit sich eine schwere Krankheit zuzuziehen, eine allgemein schlechte Gesundheit zu haben sowie an Untergewicht zu leiden. Dazu verursachen Überschwemmungen durch erhöhte pro-Kopf-Ausgaben auch finanzielle Kosten für die Haushalte. Die Ergebnisse einer Analyse von Bewältigungsstrategien zeigen, dass die Auswirkungen von Überschwemmungen auf die menschliche Gesundheit schwer zu bewältigen sind; wir finden keine wirksame Bewältigungsstrategie für die Flut-bedingten Auswirkungen auf die Gesundheit.

Die Ergebnisse in Kapitel 2 zeigen sowohl negative als auch positive Auswirkungen von Flut auf die Landwirtschaft. Während Überschwemmungen zwar Ausgaben erhöhen und Einkommen senken, können sie aber auch den Reisertrag steigern. Dieses Kapitel beleuchtet ebenfalls das Konzept der Vulnerabilität; es legt nahe, dass eine Gruppe von Menschen verwundbarer wird, wenn wir Ergebnisse mit monetären Werten messen, nicht aber, wenn wir Ergebnisse nur nach Quantität messen.

Kapitel 3 zeigt überzeugende Beweise dafür auf, dass Überschwemmungen eine Vielzahl von negativen Auswirkungen auf die Wohlfahrt der Haushalte haben. Überschwemmungen verringern das Einkommen von Haushalten aus landwirtschaftlichen Quellen und verdrängen Landwirte somit aus den Feldern, um zusätzliche Einnahmen aus nichtlandwirtschaftlichen Tätigkeiten zu erzielen. Darüber hinaus erhöhen Überschwemmungen alle Kategorien des Haushaltskonsums. Alle diese Ergebnisse werden durch die Ermittlung eines niedrigeren subjektiven Wohlbefindens im Haushalt bestätigt.

Der wichtigste Beitrag dieser Dissertation ist, dass wir das bisher ungeklärte Rätsel über die Auswirkungen von Überflutung auf die Wohlfahrt der Haushalte aufgelöst haben.

1. FLOODING IN RURAL SOUTHEAST ASIA: HEALTH IMPACTS

Abstract: This research combines an external long-term flood data extracted from satellite images with a rich panel data set of household surveys to examine the effects of floods on human health in Southeast Asia. The range of effects at both individual level and household level are examined. The key finding is that floods create a burden on human health. At individual level, floods are associated with an increase of 3.1% in the likelihood of being underweight, and of 10.6% in the likelihood of contracting serious disease. As a result, household expenditure per capita is increased by approximately 49%. We investigate a variety of coping strategies; the results tell us that the effects of floods on health are really difficult to cope with. We do not find a significant degree of success in coping strategies dealing with flood-related health effects.

1.1 INTRODUCTION

Floods are the hazard that cause the most disasters and have led to extensive morbidity and mortality throughout the world. According to the United Nations Office for the Coordination of Humanitarian Affairs (Bean J., n.d.) It is estimated that 9.6 million people are currently affected by flooding in Southeast Asia, with 5.3 million in Thailand alone. Flooding in Southeast Asia raises many concerns for the health and well-being of those affected. The effects of floods on human health is related directly to the location and topography of the area, as well as human demographics and characteristics of the built environment. The aim of this study is to provide evidence of the effects of floods on human health in rural Southeast Asia.

The main objective of this paper is to address three research questions: (1) "How do floods impact on individual health conditions?" (2) "How much do floods impact on health expenditure and health status at household level?" (3) "Which coping strategies are effective in dealing with health impacts of floods?" These questions are addressed by focusing on floods in Vietnam and Thailand using long-time measurement of household data, combined with an external flood indicator, which is a measure of local inundation. This is accomplished by using satellite floodwater images provided by NASA, the MODIS Near Real Time Global Flood Water (MFW). [1]

The results show that floods create a burden on human health. Individuals face an increased likelihood of contracting serious disease, experiencing general sick-health, and being underweight for persons living in more effected villages. Floods also incur a financial cost for households, evidenced by an increased expenditure per capita. The findings show that the effects of floods on human health are difficult to cope with. Although persons using private health insurance, or having support from a social network, or who are members of an asset-rich class, show some reduction in the effect of floods on the risk of serious disease, nevertheless these reductions are not significant.

The impacts of flooding on human health

According to (IPCC, 2012) climate shocks present an increase across the world, the local outcomes of climate change are uncertain in the frequency, intensity, spatial extent, or duration of weather. Researchers and policymakers recognize such change, in a context of increasing vulnerability will lead to increased stress on human and natural systems and a propensity for serious adverse effects in many places around the world. In

fact, for many countries weather shocks are listed as the most important cause the poverty which pushes households below the poverty line and keeps them there (World Bank, 2013).Asia is the most flood-affected region, accounting for nearly 50% of flood-related fatalities in the last quarter of the 20th century (Jonkman, 2005).

Reported flood-related impacts on human health are widespread and complex; floods continue to impact communities unequally and in different ways, with effects ranging from short to long-term, direct and indirect. The objective of this literature review section is to summarize the impact of floods on human health, which are studied in different areas or reviewed systematically over the world.

From 'Examination of the epidemiological evidence: systematic review' (Ahern, Kovats, Wilkinson, Few, & Matthies, 2005), a study of 212 reviewed references summaries, it is apparent that the most readily identified flood deaths are those that occur acutely from drowning or trauma, such as being hit by objects in fast-flowing waters. Flood-related injuries may occur as individuals attempt to remove themselves, their family, or valued possessions from danger. There is also potential for injuries when people return to their homes and businesses and begin the clean-up operation. In flood conditions, there is potential for increased fecal-oral transmission of disease, especially in areas where the population does not have access to clean water and sanitation. Diseases transmitted by rodents may also increase during heavy rainfall and flooding, because of altered patterns of contact. The relation between flooding and vector-borne disease is complex: on the one hand, many important infections are transmitted by mosquitoes, which breed in, or close to, stagnant or slow-moving water (puddles, ponds); on the other hand, floodwaters can wash away breeding sites and, hence, reduce mosquito-borne transmission.

Following Ahern et al, another systematic review was published of the relationship between floods and human health (Alderman, Turner, & Tong, 2012), 35 published articles over the period 2004-2011 were chosen. Floods are estimated to have caused almost 53,000 deaths globally over 10 years; most occurred in resource-poor countries and communities, primarily due to greater vulnerability to disasters and poor disaster management systems. Non-fatal injuries together with exacerbation of chronic illness are the leading causes of morbidity. Injuries can occur before, during and after the flood, throughout the clean-up phase and finally during repopulation. Floods might

cause toxic exposure-related health impacts since floodwater acts as trigger, releasing chemicals that are already stored in the environment. Floods are associated with an increased risk for communicable diseases including water-borne disease such as gastro-intestinal disease, hepatitis A and E, respiratory and skin infections, leptospirosis, and vector-borne disease caused by mosquitoes transmitting diseases. The long-term impact of floods on health is complex and not well understood. There is some evidence of effects on psychosocial health or malnutrition which have been studied. However, most studies on the effects of flooding on common mental disorders are from high- or middle-income countries, with the focus on common mental disorders such as anxiety and depression.

A few years later, in a comprehensive review (Du, Joseph FitzGerald, Clark, & Gerry FitzGerald, 2017) it is concluded that most of the existing epidemiology and economics literature shows that floods will increase the global burden of disease, morbidity, mortality, social and economic disruptions, and will place a continuing stress on health services, especially in low-resource countries. There are two other papers (Jonkman 2005) and (Fundter et al. 2008), which make a similar point: it is in low-resource countries where most major floods occur, and where vulnerability is the highest.

In particular, qualitative research suggests that symptoms of stress and mental disorder can be encountered in populations many years after the flood occurs (Tapsell & Tunstall, 2008). However, research on mental health stress caused by floods (Correa et al., 2017) shows that psychological distress can be reduced by coordinating awareness of flood risks and flood protection and prevention behaviour, developing the ability to protect oneself from physical, material and intangible damage, designing simple insurance procedures and protocols for fast recovery, and learning from previous experiences.

The strengths and limitations of different types of flood data

Measuring the impacts of natural disasters is the subject of a large literature, wherein there are currently four principal types of weather data used: ground station data, gridded data, satellite data, and reanalysis data. The most basic type of data is the ground station data, which directly observes temperature, precipitation, humidity, barometric pressure, as well as wind speed and direction. Another traditional method is respondents' subjective self-reports of what they consider as an adverse weather shock and its degree of intensity. Both methods have their own advantages. While ground data

provide a measurement of that exact location's climate, some types of weather data are not available in poor and developing countries, which face more severe constraints to their weather monitoring budget (Burke et al., 2014). Subjective measures have the advantage of being theoretically more precise at the local level than information from spatially aggregated data. However, the subjective measures suffer from both practical and methodological shortcomings (Thomas, Christiaensen, Toan, Le, & Trung, 2010). They can hardly assess varying severities of weather shocks precisely while also raising issues of endogeneity, especially when incorporated in the vulnerability of the household in question. While global meteorological databases are available, with the exception of the cyclone databases (UNEP/DEWA/GRID-Europe, n.d.) They typically do not have a high resolution.

When comparing different data sources in measuring floods and their impacts, Guiteras, Jina, and Mobarak (2015) compare rainfall data versus flooding data, and self-reports versus satellite images. Their paper makes two key contributions: first, they conclude that objective long-run time series measures of floods will allow us to study human behavioral responses to changes in the distribution of disaster events. Second, they show that rainfall and self-reported exposure are weak proxies for true flood exposure; that measurement error is likely to be correlated with important determinants of socioeconomic outcomes, and in particular mean exposure to floods.

To circumvent these weaknesses, we use an external long-run time series measures of floods based on satellite image data. Additionally, as the employed surveys do not refer directly to flood impacts, we avoid endogeneity issues related to the subjective exaggeration of the floods' impacts.

1.2 METHODOLOGY

This research uses a panel dataset of rural households in Thailand and Vietnam collected by the "DFG-FOR 756: Vulnerability to Poverty in Southeast Asia" project. This data source is combined with flood dataset retrieved from daily satellite MODIS Flood Water images (MFW) product version 4.9 provided by NASA. We use Geographical Information Systems (GIS) to reconstruct flood areas, and use Google Earth to draw neighborhoods of villages. Merging two data sources allows us to estimate the impact of varying flooding intensities on an array of health outcomes in a panel regression setup. The following sections will describe our data sources and estimation approach in more detail.

1.2.1 Household data

The household surveys were conducted in six provinces of Vietnam and Thailand. These include three provinces in Northeast Thailand and three provinces from the northern central coast and western highlands in Vietnam (see the map of study area in Appendix Figure B.1). In line with the overall objective of the project "Vulnerability to Poverty in Southeast Asia", the target population comprised rural households, which are poor or vulnerable to poverty. In full wave surveys 4,400 rural households were interviewed, flowing a three-stage cluster sampling design. In Thailand, secondary data for sampling was available down to the village level, population density and agro-ecological conditions were assumed sufficiently homogeneous, therefore an implicit stratification sampling was applied. However, provinces in Vietnam are geographically more diverse than provinces in Thailand. In order to take into account this heterogeneity, a design of strata for agro-ecological zones was applied[2]. (Hardeweg, Praneetvatakul, & Duc, 2007).

In this research, we use the data collected from four full waves in 2007, 2008, 2010 and 2013. The dropout rate over the four-year panel is relatively 5%, finally we are able to include around 4000 households in the main specification sample. The household data contains information about demographic, health, educational achievements, economic activities, agricultural activities, shocks and risks, employment, financial activities, assets and housing conditions of the sampled households. The surveys also include a section for village heads, which provides fundamental information of the villages. A full list of the relevant variables as well as their definitions may be found in Appendix Table A1.1.

For the study of how flood shocks impact on health outcomes and health expenditures, we use the information on health outcomes and socio-demographic characteristics for each household member provided in the questionnaire, also create Body Mass Index (BMI) for adult and ZBAWHO or ZWAWHO for teenage and children to calculate an

alternative health indicator "underweight" based on WHO classification.[4] From the survey, health conditions in the 12 months preceding the survey are measured as "how healthy are you" or "are you suffering from any serious disease or injury"; binary variables "sickness" and "serious disease" take a value of one if the household member reports "experiencing general sick-health" or "having suffered serious disease or injury". (See the list of serious diseases in Appendix Table A1.2.)

In the surveys, health expenditures are recorded at household level; they are the aggregate of all health-related expenditures including doctor fees, medicine, and other health care expenses. Furthermore, we create the variable of health expenditure per capita. We also look at the illness in the household through the proportion of underweight or serious diseases or sickness in households, measured by the ratio of those cases to household size.

As a rich dataset, we have sufficient information for control variables at three levels: individual, household, and village. At the individual level, we control for social demographics such as age group, gender, free health card or private health insurance usage.[5] At the household level, we control for socio-economic factors such as household wealth via the present value of assets, household size, dependency ratio. At the village level, we control for village infrastructure, the assess to sanitation and public waste disposal in village, epidemic in the village.

Further, in this research we investigate whether the health vulnerability to floods depends on the economic status of household. We use some coping strategies such as assets value, off-farm income, insurance mechanism, and social networks to capture both direct and indirect effects and illuminate the implicit costs associated by testing through their interactions.

1.2.2 Flood data

The flood data set and the flood indicators used in this study were used in two other papers of the same author Le Thi Ngoc Tu. We retrieved flood areas from daily satellite MODIS Flood Water Image (MFW). We follows the definition of flood from the Centre for Research on the Epidemiology of Disasters (CRED), which states that flooding is the "presence of water in areas that are usually dry". Within this definition, we choose to reconstruct the most important source of destruction attributable to a flood event as that part of local inundation, which is visible in satellite images (see an example in Append Figure B.4).

We use the daily satellite MFW product version 4.9, which produces daily surface and floodwater maps at approximately 250m resolution, in 10x10 degree tiles for South Indochina (see the map in Appendix Figure B.2). This area includes all six provinces in the study. MFW images are used for the period between 2003 and 2013. Afterward, in GIS we code daily MFW to keep information of the day that image was taken, and then we unify all daily MFW into yearly products. Each composited yearly image gives an estimate of surface floodwater during the time period, which contains information on the proportion of areas inundated. Figure 1 is an example of a flooding map for Hue province from May 2009 to April 2010. In order to measure flood at the village level, we need to use Google Earth to draw village boundaries because there is no available administrative map of villages in rural Vietnam and Thailand. Drawing was based on the coordinates of one point that belongs to the village [6], and also referred to the boundary of its commune, and an image of the village which can be viewed on Google Earth (see an example in Appendix Figure B.3). Finally, we take the inundated area in one year and divide it by the village's area, in order to obtain the proportion of the village area that has been inundated during the year; the value of this indicator lies between 0 and 1. This measure is the main indicator for analysis.

A limitation of using satellite images to extract floodwater is missing data [7]. Cloud cover is a challenging, as it is the tropical zone near the equator caused by high convection and energy fluxes to perform cloudy conditions and only some weeks of clear sky during monsoon season. Though compositing routines are used to limit the effects of clouds; there are no guarantees that cloud cover will break during any MODIS overpass (Ahamed & Bolten, 2017). In this research, we use 3-day composite product MFW, which is considered best to limit cloud-shadow issues. According to (Nigro, Slayback, Policelli, & Brakenridge, 2014) MODIS product is rated as almost perfect (five starts) for flood detecting in South Indochina.
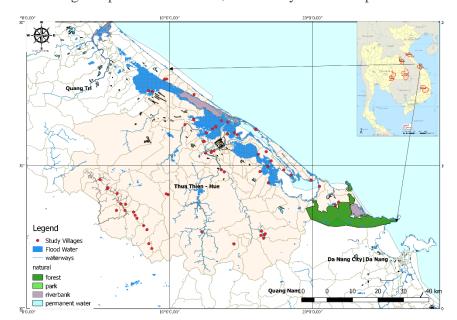
Figure 1.1: Flooding Map of Hue Province, from May 2009 to April 2010

Source: Author's calculation.

1.2.3 Descriptive statistics of the sample

Table 1.1 below provides summary statistics of the main variables used in the analysis. The sample is pooled across all four waves. On average, the age of respondents is around 33, the sample is equally split between male and female respondents with 49% are male, among those approximately 19 % are children from 0 to 6-year-old, and around 12% are older than 60-year-old. Regarding to health status in general, the proposition of individuals who are underweight is roughly 18%. Following that, the incidence of serious disease among individuals in the sample is around 16%. In general, 10% respondents reported that they experience general sick-health. Since the survey were taken in poor provinces, the percentage of people using a free health card is quite high 80%, while only 9% of the individual have private health insurance.

On average, the households in the surveys have four people in each house. Approximately, 14% of the heads of households have completed their secondary school; it is possible that low education is a factor making households more vulnerable to poverty in Thailand and Vietnam. The dependency ratio in the sample is quite high;[8] this phenomenon demonstrates that in households in rural Southeast Asia, grandparents in the villages take care of grandchildren while people in working ages work beyond their villages.

Table 1.1. Descriptive Statistics
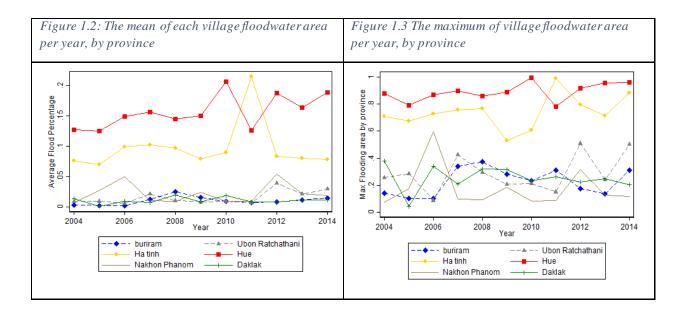
	Mean	SD	Min	Max
Individuals				
Age	33.71	20.36	0.00	110
Male (1/0)	0.49	0.50	0.00	1.00
Children (1/0)	0.19	0.40	0.00	1.00
Elder (1/0)	0.12	0.32	0.00	1.00
Underweight (1/0)	0.18	0.38	0.00	1.00
Serious disease (1/0)	0.16	0.37	0.00	1.00
Sickness (1/0)	0.10	0.29	0.00	1.00
Free health card (1/0)	0.80	0.40	0.00	1.00
Private health card (1/0)	0.09	0.28	0.00	1.00
Observation of individuals	78,472			
Households				
Household size	4.09	1.75	0.00	19.00
Education of head	0.14	0.34	0.00	1.00
Dependency ratio	0.66	0.70	0.00	6.00
Total income per capita	2112.19	5024.96	-39506.96	256944.19
Total consumption per capita	1739.62	1603.54	114.37	55966.61
Consumption per capita for foods	817.10	673.07	17.03	14611.09
Consumption per capita for rice	283.78	336.00	0.00	7529.92
Consumption per capita for health care	41.47	232.62	0.00	16560
Social network for coping (1/0)	0.69	0.46	0.00	1.00
Share underweight in household	0.24	0.32	0.00	5.00
Share serious disease in household	0.22	0.31	0.00	5.00
Share sickness in household	0.14	0.26	0.00	5.00
Observation of households	15,967			

Notes: consumption and income variables have been converted to 2005 USD.

Sources: Sample of panel household data 2007, 2008, 2010, 2013; author's calculation.

The average of annual total consumption per capita is 1740 USD; this is approximately 90% of their income per capita (2112 USD). It can be seen that the distribution of consumption is mainly for food and rice – about 65% of the total – while the expenditure on health is only 3%. The rural people seem to have a close bond with the surrounding community: there are 69% of households reporting that they have someone in the community to call on when they suddenly need money (such social networks consist of relatives, friends, neighbors, pawnshops, informal moneylenders, or village funds).

Regarding the health status in households, within each household the average proportions of members who are underweight or suffering from serious disease or experiencing general ill-health are 24%, 22%, and 14% respectively.

Figure 1.2: The mean of each village floodwater area per year, by province	*Figure 1.3 The maximum of village floodwater area per year, by province*

Flood data of 440 villages in 10 years.

Source: author's calculations.

The Figure 1.2 shows the average proposition of each village floods per year by province. The two most affected provinces are Hatinh and Hue in Vietnam, which continuously exhibited larger average flood levels, the two least affected provinces are Buriram in Thailand and Daklak in Vietnam. While Figure 1.3 shows the maximum of village flood areas per year by province. The most affected villages in Hue province - Vietnam experience between 80 – 99% of floodwater area. The variation of the maximum floodwater areas fluctuates throughout the year, but the most affected villages have large floods in every year.

1.2.4 Empirical strategy

(Kaufman, 2008) notes that greater attention to causal inference has been one of the most important trends in social epidemiology over the last decade. Many techniques have become standard in econometrics and social sciences, including multilevel modeling, propensity score matching and instrumental variables. One such technique, exploited cleverly in several articles is the fixed effects regression model, which relies solely on within-individual changes, eliminating confounding by all the innumerable and unmeasurable influences. This is a truly remarkable virtue of the fixed effects model, and one that makes it so attractive for social epidemiology, where exposures are often heavily confounded by myriad contextual, behavioral and attitudinal quantities that would be difficult to assess exhaustively.

Observational health studies frequently deal with grouped or clustered data. When observations are clustered into groups, common group-level characteristics can affect outcomes. If all of these unique characteristics are observed and measured, it would be possible to include them in a model, although in most cases this is unrealistic. Some examples of unobserved such as quality of diet, exercise, generic, predisposition, culture … may or may not influence the predictor variables. Since we are only interested in analyzing the impact of floods on health that vary over time, and we also want to control for factors within individual may impact or bias the health outcome variables, fixed effect regression models are used in this research.

The equation for the fixed effect model at individual identification:

$$H_{it} = \gamma_i + \alpha_1 F_{vt} + \beta X_{it} + \rho_t + \varepsilon_{it} \ (1),$$

In which an outcome H_{it} and an independent variable X_{it} are observed for each individual i over multiple time periods t (waves), and a mutually exclusive intercept shift γ_i is estimated for each individual i to capture the distinctive, time-invariant features of each individual. This results in an estimate of α_1 or β that is purged of the influence of between-unit time- invariant confounders.

The individual health outcome H_{it} is measured in three ways, namely: (a) a binary underweight indicator is based on WHO classification, (b) a binary disease variable takes a value of one for individual reports of persons having suffered a "serious

disease or injury", (c) a binary sickness variable takes a value of one if individual reports state that he/she has the general health status "sick".

F_{vt} represents the flood indicators, by which the average of the proportion of a village's area that has been covered by floodwater in the previous and the year of survey, F_{vt} is a continuous value from 0 to 1.

We assume that health outcomes are determined by the household characteristics related to quality of life such as household size, education of household head, the household economic status measured by present value of assets (lagged by one survey wave to avoid capturing the direct effects of flood on household assets), cooking methods, and presence of private toilet. Moreover, the living standard in a community includes epidemic in village, time from village to the district town (in minutes), access to sanitation, access to waste disposal, and village infrastructure index.

ρ_t is the wave fixed-effects to account for unobserved difference between survey years. And ε_{it} is the error term with standard errors clustered at the village level.[9]

Fixed-effects models are designed to study the causes of changes within a person. The key insight is that if the unobserved variable does not change over time, then any changes in the dependent variable must be due to influences other than these fixed characteristics (James H. Stock ; Mark W. Watson, 2003). Thus, the coefficient of interest is α_1, which is estimated based on deviations from each unit's average treatment value over time.

Vulnerability, broadly defined as the potential for loss, is an essential concept in hazard research, and is central to the development of hazard mitigation strategies at the local, national and international level (Cutter, 1996). There are subtle yet complex differences in regard to where vulnerability is placed in the conceptual 'chain of events' (James Lewis, 1999), or where authors seem to refer to vulnerability as an outcome (Downing, Olsthoorn, & Tol, 1999): 'the degree of loss resulting from a potentially damaging phenomenon.' While (Neil Adger, 1999) provides a similar definition, 'the exposure of groups or individuals to stress as a result of social and environmental change, where stress refers to unexpected changes and disruption to livelihoods', (Winser, Blaikie, Cannon, & Davis, 2005) defines vulnerability as 'characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of natural hazards.' In most papers on vulnerability to floods, which

focus on the household or individual level, the most vulnerable groups are low-income peoples, migrants, those without insurance or financial reserves, the elderly, and the infirm (Few, 2003). While some authors show the connection between poverty and vulnerability (Tran, Marincioni, Shaw, Sarti, & Van An, 2008), others like (McElwee, Nghiem, Le, & Vu, 2017) conclude that poverty alone cannot explain flood vulnerability. (Douglas, 2009) in a study of floods in South Asia shows that the most vulnerable groups in terms of food security during floods under climate change are women, children, and the poor. A systematic review (Rufat, Tate, Burton, & Maroof, 2015) finds that demographic characteristics are among the most commonly applied social vulnerability indicators and that women and the elderly are often considered among the most vulnerable.

Whereas the equation (1) assumes that all individuals or households in the sample have a homogeneous health response toward flood shocks, demographic and social-economic characteristics might be important factors that determine how flood impacts on health outcomes. In our next step, we investigate the vulnerability to flooding by interacting the flood variable with variables representatives for different groups such as females and age groups.

To investigate the differences of effects on different groups we use the model (1) and add the interaction term $\alpha_2 F_{vt} * I_i$, in which I_i indicates the individual identification such as female or age group. The coefficients of interest are α_1, α_2 and $\alpha_1 + \alpha_2$.

Furthermore, whether a household suffers a health shock is likely to be related to both its shock prevention strategies toward such a shock ex-ante, for instance, where there is an insurance mechanism, as well as its ability to cope with the shock ex-post such as from household assets or calling on a social network for help. (Javier Esparcia*, 2016; Paul et al., 2014; Wiesinger & Georg, 2007) discussed in regard to rural areas, how the informal social network plays an important role for development, networking, and decision-making; since it is not required for many administrative processes, this makes the social network more accessible for rural people to reach in order to be better prepared for economics shock in the time of need. In order to classify this argument, we entered Social network as a coping strategy into the analysis. In the household survey is included a section for Shocks coping strategy, in which some questions are related to informal sources that a household can draw on when they suddenly need money. These

informal networks consist of relatives, friends, neighbors, pawnshop, informal money-lender, or village funds. The data shows that approximately 69% of households have at least one informal network to ask for in the time of need, and the majority has more than two options.

In order to examine the role of coping strategies in reducing the effects of floods on individual health conditions, we use the model (1) and add the interaction term $\alpha_3 F_{vt} * C_{hvt}$, in which C_{hvt} indicates the set of coping mechanisms including: public or private health insurance, intra-house insurance schemes such as (assets, saving, off-farm income, social network). The coefficients of interest are α_1 , α_3 and $\alpha_1 + \alpha_3$.

To gauge the effects of floods on health at household level, the panel data of household ID is identified; then we use a fixed effect model to analyze the relationship between floodwater in village with health conditions in households.

The equation for the fixed effect model at household identification becomes:

$$H_{ht} = \gamma_h + \alpha_1 F_{vt} + \beta X_{ht} + \rho_t + \varepsilon_{ht} \text{ (2),}$$

In which an outcome H_{ht} and an independent variable X_{ht} are observed for each household h over multiple time periods t (waves), and a mutually exclusive intercept shift, γ_h , is estimated for each household h to capture the distinctive, time-invariant features of each household. This results in an estimate of α_1 or β that is purged of the influence of between-unit time-invariant confounders.

The health condition in household H_{ht} is measured in four ways, namely: (a) annual health expenditure per capita (logged), (b) share underweight in household, (c) share serious disease in household, (d) share sickness in household.

We assume that health conditions in households are determined by the household characteristics related to quality of life such as: share age group, the household economic status measured by present value of assets (lagged by one survey wave to avoid capturing the direct effects of flood on household assets), cooking methods, private toilet. Living standard in community is also controlled in the models, such as: epidemic in village, time from village to the district town, access to sanitation, access to waste disposal, and village infrastructure index.

1.3 FINDINGS

This section of the paper presents the empirical results of our analysis. We use the proportion of floodwater area in villages as the main indicator of flood. First, we examine the effects of floods on health at individual level. Second, we investiage the effects of floods on health conditions at household level. Further, we verify coping strategies through formal and informal insurance mechanisms. All the results shown use heteroscedasticity robust standard errors clustered at the village level.

1.3.1 The effects of floods on health conditions at individual level

Table 1.2 shows the effects of flood on health conditions at individual level. There are three measures used as health outcomes; underweight indicator, individual suffering from a serious disease, individual reporting of experiencing general sick-health. In general, increasing floodwater area associates with higher likelihood of bad health condition. Column (1-3) show that variation of floodwater (from 0 to 1) in a village results in an increased 3.5% of being underweight, increased 10.7% of contracting serious disease, and an increased 6.1% of experiencing general sick-health for individuals living in that village.

Table 1.2: The relationship between floodwater and individual health conditions

	(1) Underweight	(2) Serious Disease	(3) Sickness
Flood	0.035	0.107*	0.061
	(0.57)	(2.00)	(1.22)
Observations	56103	56671	58391
Adjusted R2	0.521	0.381	0.335
Individual-FE	Yes	Yes	Yes
Wave-FE	Yes	Yes	Yes

Fixed effect regressions. Standard errors, clustered at village level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$;

Dependent variables: (1) Individual is underweight (1/0), (2) Individual suffers from serious disease (1/0), (3) Individual experience general sick-health (1/0);

Other controls: Household variables, Village variables.

Source: Author's calculation. (The detail result table is provided in Appendix A1.3).

In the household surveys, health data is collected in general, not referring directly to flood impacts. This may help to avoid subjective exaggeration of the impacts, but also could lead to inaccuracies from a lack of recall due to the time elapsed, a lack of

understanding of the symptoms and responses of other household members, and the impact of intervening events. These limitations could lead to underestimating the impact of floods on the incidence of serious diseases.

Another possible hypothesis is the familiarity of the situation. People who have lived in a flood-prone area for years (probably many generations have lived in the same village) become accustomed to the situation. Therefore, their assessment of their general health status may not be different with people living in other areas. This hypothesis might alleviate the estimation of impact of floods on general health status (experiencing general sick-health). To verify this hypothesis, we run two separate regressions for two provinces: Hue is the most affected province, and Buriram is the least affected province.

The Table 1. 3 represents results for two provinces.

Table 1.3: Floodwater and individual health, two provinces: Buriram and Hue

	(1) Underweight	(2) Serious Disease	(3) Sickness
Buriram			
Flood	0.107	0.246*	0.220*
	(1.19)	(2.20)	(2.21)
Hue			
Flood	0.048	0.157	0.057
	(0.28)	(0.85)	(0.48)
Individual - FE	Yes	Yes	Yes
Other control	Yes	Yes	Yes

Individual Fixed effect regressions. Standard errors, clustered at village level. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$;

Dependent variables: Individual Underweight (1/0), Individual suffers from serious disease (1/0), Individual's general health condition is sickness (1/0);

Other controls: Household variables, Village variables.

Source: Author's calculation.

The results in Table 1.3 tell us that: at the same level of flooding, people in Buriram find it much more serious than people in Hue. In Buriram, individual report of experiencing general sick-health in a significant higher rate 22%, while that is only 5.7% in Hue province. Perhaps, flooding in Buriram is rare, so when floods present, people feel its impact exacerbated.

Table 1.4 presents the effect of floods on individual health for different groups. The results in column (1-3) tell us that female are more vulnerable than male with being underweight and experiencing general sick-health but less vulnerable with contracting serious disease. The results in column (4) indicates no clear difference in the effect of floods on 'underweight' in different age groups. Column (5) and (6) indicate that

working age group people (20-60) are more vulnerable to flood related issues, floodwater increases their probability of getting serious disease and experiencing general sick-health increases to approximately 14.6% and 7.2%. In general situations, relative to the reference group of 20-60-year-old, the coefficients of children and young people (group 0-19) are more likely to contract a serious disease, and old people are more likely to be feeling sick. However, in flood-related health effects, people in working age group (20-60) are more vulnerable. Perhaps, this group are members who a directly involved in coping activities, traveling and taking main responsibility for the whole family, therefore their exposure to floodwater is more than other groups.

Table 1.4: The relationship between floodwater and illness

	(1)	(2)	(3)	(4)	(5)	(6)
	Underweight	Serious Disease	Sickness	Underweight	Serious Disease	Sickness
Flood	-0.038	0.127*	0.027	0.042	0.146*	0.072
	(-0.54)	(2.17)	(0.51)	(0.59)	(2.51)	(1.39)
Flood* Female	0.157	-0.037	0.09			
	(1.14)	(-0.36)	(1.25)			
Flood* Age group (0-5)				-0.01	-0.103	-0.017
				(-0.05)	(-1.36)	(-0.26)
Flood* Age group (6-19)				0.007	-0.063	-0.015
				(0.09)	(-1.36)	(-0.47)
Flood* Age group (>60)				-0.067	-0.202	-0.073
				(-0.36)	(-0.90)	(-0.40)
Age group (0-5)				-0.038	-0.01	-0.002
				(-1.52)	(-0.74)	(-0.16)
Age group (6-19)				-0.104***	-0.002	-0.004
				(-8.67)	(-0.21)	(-0.60)
Age group (>60)				0.023	0.019	0.045*
				(1.44)	(0.85)	(2.05)
Observations	54464	54971	56648	56103	56671	58391
Adjusted R2	0.521	0.382	0.337	0.523	0.381	0.335
Individual –FE	Yes	Yes	Yes	Yes	Yes	Yes
Wave - FE	Yes	Yes	Yes	Yes	Yes	Yes
Other control	Yes	Yes	Yes	Yes	Yes	Yes

Fixed effect regressions. Standard errors, clustered at village level. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$;

Dependent variables: (1) and (4) Individual is underweight (1/0), (2) and (5) Individual suffers from serious disease, (3) and (6) Individual experience general sick-health (1/0);

Other controls: Household variables, Village variables.

Source: Author's calculation.

1.3.2 The effects of floods on health conditions at household level

Table 1.5 shows the effects of floods on health at household level both physically and financially. Columns (1-3) present an increased probability in every aspect of health outcomes at household level; variation of floodwater (from 0 to 1) in a village results in an increased by 5.6% in the share who are underweight in household, by 16.2% of the share who are suffering serious disease, and an increase by 19.9% of the share who are reporting general sick-health. As a result, increased health expenditure overall per capita is roughly 43.5% (equivalent to 1.5 times).

Table 1.5: The relationship between floodwater and health in households

	(1) Underweight	(2) Disease	(3) Sickness	(4) Health Expense
Flood	0.056	0.162	0.199[*]	0.435
	(0.53)	(1.33)	(2.22)	(0.63)
Observation	8146	8146	8146	7685
Adjusted R2	0.604	0.346	0.401	0.336
Household - FE	Yes	Yes	Yes	Yes
Wave - FE	Yes	Yes	Yes	Yes

Fixed effect regressions. Standard errors, clustered at village level. $^* p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$;

Dependent variables: (1) Share Underweight in house, (2) Share serious disease in house, (3) Share sickness in house, (4) Log of health Expenditure per capita;

Other controls: Household variables, Village variables.

Source: Author's calculation. (The detail result table is provided in Appendix A1.4).

1.3.3 Coping through formal and informal insurance mechanisms

From a policy perspective it will be useful to identify which coping mechanisms are best suited to reduce flood related health vulnerability. Table 1.6 presents results for coping strategies, modelled by interacting the floodwater indicator with variables reflecting various coping strategies variables in household survey. Negative coefficients on the interaction terms would indicate that coping strategies reduces health vulnerability to flood.

We investigate whether the coping strategies can reduce the likelihood for individual from contracting serious diseases. Unfortunately, we do not find a significant reduction in serious disease due to coping strategies attempted. In column (1), poor people who are using free health card seem to be even more vulnerable with around 8.7% higher probability than non-poor people. Since the free health for poor mainly targets household vulnerable to poverty and economic shocks, it is reasonable that members of these

households generally display higher risk. Column (2) shows a small reduction of about 3.2% for individuals using private health insurance. Intra-house insurances such as assets, off-farm income and social network display nearly no effect.

Table 1.6: Coping strategies and serious diseases

	(1) Serious Disease	(2) Serious Disease	(3) Serious Disease	(4) Serious Disease	(5) Serious Disease
Flood	0.039	0.110*	0.171	0.094	0.113
	(0.67)	(2.09)	(1.17)	(1.81)	(1.85)
Flood*Free Health Card	0.087				
	(1.94)				
Flood* Private Health Insurance		-0.032			
		(-0.68)			
Flood* Assets value			-0.008		
			(-0.49)		
Flood*Off-farm income per cap				0.006	
				(1.03)	
Flood*Social Network					-0.014
					(-0.37)
Free Health Card	0.008				
	(1.09)				
Private Health Insurance		0.013			
		(1.68)			
Assets value, lagged			0.003		
			(1.81)		
Off-farm income per cap, logged				0.002*	
				(2.35)	
Social Network					0.016***
					(3.50)
Observations	56640	56671	56671	56667	56671
Adjusted R2	0.381	0.381	0.381	0.381	0.382
Individual-FE	Yes	Yes	Yes	Yes	Yes
Wave-FE	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes

Fixed effect regressions. Standard errors, clustered at village level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$;

Dependent variables: Individual suffers from serious disease (1/0).

Other controls: Household variables, Village variables.

Source: Author's calculation.

The results relating to free health card and private health insurance in this section should be understood as indicative, rather than casual effects. Regarding to private insurance, self-selection might play a major role since people are using private insurance more likely because they are suffering from a worse health condition. In addition, regarding to free health card, in developing countries like Vietnam and Thailand, using free health card sometimes brings a bad experience for patients. When patients go to hospitals with a free public health card, they have to wait longer to receive the service, the treatment procedure often is more complicated than commercial service, and sometimes patients also receive cold attention from doctors; therefore in many cases they choose other services for better treatments (Jeffrey Hays, 2012). Therefore, the insignificant coefficients might not justify making direct inferences about free health card program, but possibly reflect the ways it is implemented in the healthcare systems.

1.4 CONCLUSIONS

This study provides an evidence of flood impacts on human health in Southeast Asia by analyzing two levels of impacts; individual level and household level. The advantage of this study is using external data sets on local flood maps obtained from satellite observations to measure floodwater; this has the advantage of highly precise and objective geographical satellite data. The results show that floods create a burden on human health. Individuals face an increased likelihood of contracting serious disease, experiencing general sick-health, and being underweight if floodwater in their villages is increasing. Floods also cause a financial cost for households with an increased expenditure per capita. The findings from an analysis of coping strategies show a fact that the effects of floods on human health are difficult to cope with; we do not find any effective coping strategy dealing with flood-related health. These findings are useful for policy makers to identify which coping mechanisms might be better suited to reduce flood related health vulnerability, and which ways might be effective to establish those coping strategies.

NOTES

(1) MODIS Flood Water (MFW), and MODIS Surface Water (MSW): Currently these are only distributed as vector products (shapefile and kmz) for standard composites. MSW gives all land-based water (with a buffer into oceans) that was observed in the given product. MFW removes from MSW a reference or expected water layer, such that the remaining water is likely to be floodwater.

(2) The German Research Foundation (DFG) in Bonn, Germany in 2006 has awarded a special research unit to the Universities of Hannover, Göttingen, and Frankfurt. The subject of the project is the analysis of the role of shocks and risks for the development of poor countries and emerging market economies.

(3) Secondary data for sampling on Thailand was available down to the village level; population density and agro-ecological conditions were assumed to be sufficiently homogeneous; sample design for Thailand is kept simple and aimed at obtaining a self-weighting sample. The provinces in Vietnam were purposively selected for the survey and are geographically more diverse than those in Thailand. While Dak Lak province is part of the landlocked Central Highland, Thua Thien-Hue, and Ha Tinh provinces extend from the coast to the mountainous border to Laos. In order to take into account this heterogeneity, strata for the first stages were defined as agro-ecological zones within the three provinces.

(4) WHO classification for adult BMI, BMI for age 5-19 years (zbwho), and weight for age 0-5 years (zwawho)

Obese	Adult BMI >=30; zbawho >=2; zwawho>=3
Overweight	Adult BMI [25, 30) ; zbawho [1, 2) ; zwawho (2, 3)
Normal range	Adult BMI [18.5, 25) ; zbawho [2, 1); zwawho [-2, 2]
Thinness	Adult BMI [16, 18.5) ; zbawho [-3, -2); zwawho[-3, -2)
Severe thinness	Adult BMI <16; zbawho <-3; zwawho <-3

(5) In Thailand, since 1975, the Government had made health services available to the poor free of charge. However, the Universal Coverage Scheme (USC) has followed a long string of efforts to improve equity in health. By 2001, the UCS was covering 48 million members and their families, leaving less than 2 percent of the Thai population without health insurance coverage (Wagstaff & Manachotphong, 2012).

In Vietnam, to improve health care access for low income households, the Vietnamese Government offers the program Health Card for the Poor in 2003. This card was designed to support poor households and ethnic minorities. The program covers inpatient and outpatient health care costs at public providers (Somanathan, Tandon, Dao, Hurt, & Fuenzalida-Puelma, 2014).

(6) For each village, one coordinate was recorded by the interviewers during the village interviews. The coordinates were recorded in decimal degrees (latitude, longitude). For example, the geographical coordinates of the village Yang, sub-district Kham Duan, district Krasang, province Buriam, Thai land is (15.0773638888889, 103.401458333333).

(7) Another limitation of using satellite images is that satellite images of floodwater can only capture the surface of water, but cannot measure the depth of water.

(8) The dependency ratio is a measure showing the ratio of the number of dependents aged zero to 14 and over the age of 65 to the total population aged 15 to 64. This indicator gives insight into the amount of people of nonworking age compared to the number of those of working age. The ratio can be calculated as:

Dependency Ratio = (Number of dependents / Population aged 15 to 64) x 100%

(9) The standard errors are clustered at village level due to sampling design. The survey used a three-stage clustered sampling approach. Provinces were targeted, sub-districts were selected with probability proportional to population size (PPS), followed by a simple random PPS sample of two villages from each sampled sub-district. Lastly, households were randomly sampled with implicit stratification by household size. We account for the survey design using sample weights.

APPENDIX A1

Table A 1.1: Variable definitions

Variable	Definition
Access to public waste disposal	Percentage of households in village with access to public waste disposal
Access to public water	Percentage of households in village with access to public water
Access to sanitation	Percentage of households in village with access to sanitation
Children (1/0)	Dummy variable, takes the value 1 if member belongs to aged group 0-15
Cooking fuel (1/0)	Dummy variable, takes the value 1 if household uses gas or electric for cooking
Dependency ratio	Number of dependents / number of aged 15 to 64
Elder (1/0)	Dummy variable, takes the value 1 if member is older than 60
Epidemic in village (1/0)	Dummy variable, takes the value 1 if village has epidemic problem
Free health card (1/0)	Household has free health card
Head education	Categorical variable, which takes values 0-6 0: No education 1: Primary not completed 2: Primary completed 3: Lower secondary completed 4: High school/ vocational completed 5: Some college / advanced vocational completed 6: University or higher
Health expenditure per capita	The aggregate of health-related expenditure per capita
Household Assets	Household total present value of asset items
Household income per capita	Household total annual income per capita
Household size	Household nucleus size, includes only members of the family who stay in the household for more than 6 months
Private health insurance (1/0)	Dummy variable, takes the value 1 member has private health insurance
Private toilet (1/0)	Household has a private toilet
Serious disease	Dummy variable, takes the value 1 if member reported "having suffered from serious disease or injury" in the 12 months preceding the survey
Share children	Proportion of children in household = (number of aged from 0 to 15 / household size)
Share elder	Proportion of in household = (number of aged from 60 / household size)

Share infant	Proportion of infant in household = (number of aged from 0 to 5 / household size)
Sickness	Dummy variable, takes the value 1 if member reported "experiencing general sick-health" in the 12 months preceding the survey
Social network	Dummy variable, takes the value 1 if household has someone to ask for money when they suddenly need, the network consists of relative, friends, neighbors, pawnshop, informal moneylender, or village funds
Time to town	Travel time from village to the district town in minutes
Underweight	Dummy variable, takes the value 1 if member is thin or severe thin according to WHO classification
Village infrastructure	Village infrastructure index in quintiles

Notes: Expenditure and income variables have been converted to 2005 USD

Source: Author's calculation

Table A 1.2 : List of diseases

List of diseases

1. Pneumonia	29. Hypertension
2. Cataract and other disorders of lens	30. Coronary heart disease
3. Ischaemic heart diseases	31. Valvular heart disease
4. Diarrhea and gastroenteritis of presumed infectious origin	32. Fractures of other limb bones
5. Cervical Cancer/ Cancer of Cervix	33. Other accident-related injuries
6. Diseases of appendix	34. Infection in blood circle
7. Malignant neoplasm of lip, oral cavity and pharynx	35. Bellyache
8. Malignant neoplasm of breast	36. Abedan
9. Lung cancer	37. Deaf
10. Breast cancer	38. Alcoholism
11. Leukemia	39. Headache
12. Cerebral infarction	40. Decreased bone mass
13. Diphtheria	41. Calculus of kidney
14. Pertussis	42. Asthma
15. Tetanus	43 Cholelithiasis
16. Poliomyelitis	44. Blind
17. Measles	45. Down-Syndrom
18. Rubella	46. Artificial kidney
19. Mumps	47. Back ache
20. Encephalitis	48. Absent minded
21. Hepatitis B	49. Agent organge related disease
22. Tuberculosis	50. Asthenic
23. Epilepsy	51. Bronchitis
24. AIDS (Acquired Immune Deficiency Syndrome)	52. Arthralgia
25. Acute diarrhea	53. Lymph nodes of the neck
26. Dengue Hemorrhagic Fever	54. Bleeding per rectum
27. Influenza	Others
28. Diabetes mellitus	

Source: Household Survey Vietnam/ Thailand 2013, version 5.4.

Table A 1.3: The relationship between floodwater and individual health conditions

	(1) Underweight	(2) Serious Disease	(3) Sickness
Flood	0.035	0.107*	0.061
	(0.57)	(2.00)	(1.22)
Age group	0.0369***	0.00796	0.00961
	(3.93)	(1.21)	(1.59)
Household Size	0.00139	-0.00414	0.00211
	(0.86)	(-1.91)	(1.26)
Dependency Ratio	0.00523	0.000190	0.00482
	(1.17)	(0.04)	(1.21)
Assets value, lagged	0.000169	0.00271	0.00179
	(0.12)	(1.74)	(1.41)
Head Education	0.00423	0.00685	0.00218
	(0.94)	(1.30)	(0.54)
Cooking Fuel	0.00580	0.00442	-0.00163
	(1.23)	(0.73)	(-0.33)
Private Toilet	-0.00571	0.00665	-0.00291
	(-0.93)	(0.94)	(-0.56)
Time to Town	0.000141	-0.000660**	-0.0000694
	(0.88)	(-3.06)	(-0.36)
Village Infrastructure Index	0.00195	-0.00374	0.00223
	(0.95)	(-1.29)	(0.91)
Epidemic in Village	-0.00380	0.0207	0.00891
	(-0.45)	(1.70)	(0.99)
Access to Sanitation	0.0000626	0.000381***	0.000209***
	(1.13)	(4.85)	(4.06)
Access to waste disposal	-0.000108	-0.000184	-0.0000139
	(-0.99)	(-1.31)	(-0.15)
_cons	0.0995***	0.142***	0.0252
	(4.25)	(5.90)	(1.25)
Observations	56103	56671	58391
Adjusted R2	0.521	0.381	0.335
Individual-FE	Yes	Yes	Yes
Wave-FE	Yes	Yes	Yes

Fixed effect regressions. Standard errors, clustered at village level. $^* p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$;

Dependent variables: (1) Individual is underweight (1/0), (2) Individual suffers from serious disease (1/0), (3) Individual experience general sick-health (1/0);

Other controls: Household variables, Village variables.

Source: Author's calculation.

Table A 1.4: The relationship between floodwater and health in households

	(1) Underweight	(2) Disease	(3) Sickness	(4) Health Expense
Flood	0.056	0.162	0.199*	0.435
	(0.53)	(1.33)	(2.22)	(0.63)
Assets value, lagged	-0.0114*	-0.00449	-0.00623	-0.0233
	(-2.27)	(-0.72)	(-1.23)	(-0.70)
Epidemic in Village	-0.00906	0.0186	0.0166	0.223*
	(-0.81)	(1.03)	(1.30)	(2.29)
Access to Sanitation	0.000279**	0.000841***	0.000415***	0.000837
	(2.97)	(6.78)	(4.88)	(1.29)
Access to waste disposal	-0.000202	-0.000338	0.0000806	-0.00233
	(-1.17)	(-1.45)	(0.53)	(-1.69)
Share infant in house	0.209***	0.0871	-0.0154	
	(4.31)	(1.32)	(-0.35)	
Share elder in house	0.425***	0.280***	0.176***	
	(7.72)	(6.00)	(4.07)	
Private Toilet	-0.0132	-0.00577	-0.0133	
	(-1.19)	(-0.45)	(-1.35)	
Cooking Fuel	0.0169	0.0219	0.0116	
	(1.66)	(1.56)	(0.96)	
_cons	0.234***	0.142**	0.139***	2.257***
	(6.38)	(2.91)	(3.56)	(9.17)
Observation	8146	8146	8146	7685
Adjusted R2	0.604	0.346	0.401	0.336
Household - FE	Yes	Yes	Yes	Yes
Wave - FE	Yes	Yes	Yes	Yes

Fixed effect regressions. Standard errors, clustered at village level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Dependent variables: Share Underweight in house, Share serious disease in house, Share sickness in house, Log of health Expenditure per capita

Other controls: Household variables, Village variables

Source: Author's calculation

2. THE EFFECTS OF FLOODS ON AGRICULTURAL PRODUCTION: A MIXED BLESSING

Abstract: Studies of the flood impacts on agriculture have reported the whole picture of negative effects, as agricultural production is heavily influenced by weather and climate. This research will demonstrate that the effects of floods on agriculture production are a mixed blessing. We use a rich panel data set of rural household surveys and external long-term flood data extracted from satellite images to examine the effects of floods on agricultural production in Southeast Asia. The findings show both negative and positive effects of floods on agriculture. While floods increase expenditures and reduce incomes, they can also increase rice productivity. Impacts due to vulnerability to floods are observed when agriculture outcomes are measured in monetary values such as household expenditures and household incomes, but that evidence of vulnerability disappears when outcomes are measured as a quantity in term of rice productivity.

2.1 INTRODUCTION

The effects of floods on agriculture production

According to (IPCC, 2012), the frequency of climate shocks presents an increasing risk across the world. Local outcomes of climate change are uncertain in frequency, duration, intensity or spatial extent. Researchers and policymakers recognize that, in a context of increasing vulnerability, such changes will lead to increased stress on human and natural systems. Studies on climate change also show that floods are increasing in Asia and bring many negative effects to human populations as well as agricultural production. The main objective of this paper is to address two research questions: (1) "How do floods impact on agriculture production if outcomes are measured in multi-dimensional aspect?", and (2) "which group of households are more vulnerable to floods in term of agriculture production?"

These questions are addressed by focusing on floods in Vietnam and Thailand using long-time measurement of household welfare, combined with an external flood indicator, which is a measure of local inundation by using satellite floodwater images provided by NASA, the MODIS Near Real Time Global Flood Water (MFW).[1] As expected, we find a negative effect of floodwater on crop income, hunting income, and livestock income, floods also increase significantly all kind of expenses for crop production. On the other hand, a higher floodwater intensity is associated with higher rice productivity. At the same time, we observe a change in the impacts attribute to this vulnerability when we change the way of measuring outcomes on the same subject of study.

Natural disasters and household welfare evidence from Vietnam (Thomas et al., 2010) provides an approach to understanding how much natural disasters affect local economies and their people. These authors derive measures of natural disasters and hazards at disaggregated geographical levels from primary meteorological weather station data, storm tracks, and satellite observations. While the (economic) literature typically uses subjective measures of shocks and disasters. Their results indicate that short-run losses from natural disasters can be substantial with riverine floods causing welfare losses of up to 23 percent and hurricanes reducing welfare by up to 52 percent inside cities with a population of over 500,000.

Among the literature considering impacts of floods on agricultural livelihoods, one paper uses quantitative methods. (Banerjee, 2010) examines the impact of floods on

rice production in Bangladesh, and argues that although severe inundation destroys crops during the monsoon flood months, monsoon floods act as an open-access resource in supplying irrigational input to agriculture. The author distinguishes floods into two categories: "more" and "less" flood-prone districts, based on the Bangladesh National Water Plan. The results show that the area under cultivation and agricultural productivity are higher in the "more" flood-prone districts of Bangladesh. They also show that while yield rates decline when floods assume "extreme" proportions, productivity increases during "normal" floods and in the post-flood months. The impact of repeated flooding is examined by comparing agricultural performance in districts that vary in terms of their relative exposure to inundation. In our research, we quantify floodwater area at the village level. With the effect on the rice productivity measured at household level, we find similar effects.

(Tran et al., 2008) study flood risk management in Thua Thien Hue, Central Vietnam. They explore the impacts of floods on the economy, environment and society, and try to clarify the rural community's coping mechanism to flood disasters using a mixed method methodology. The results show that annual floods bring significant damage to agriculture and aquaculture by destroying crops in rice fields, sweeping away aquaculture products, or ruining fish and shrimp ponds. Despite these negative impacts, the survey revealed that a high percentage of respondents think that floods help to clean the environment. Floods bring alluvium to agricultural land and kill insects and rats. Some respondents even claimed that every 3 years a big flood is needed to refresh the lagoon environment. Many respondents agreed that the production of aquaculture and agriculture increase after a large flood. However, their approach only allows (Tran et al., 2008) to make a subjective assessment of the effect of floods on agriculture. In this paper, we supplement their research by quantitatively re-investigating their conclusions in a larger sample of households.

In the face of globally increasing floods, the approach of "living with floods", rather than relying on structural flood control and prevention measures, is acquiring greater momentum (Eakin & Appendini, 2008). This study on livelihood change, farming, and managing flood risk in the Lerma Valley in Mexico, argues that if people only focus on the negative effects and find solutions by changing economic structures, characterized by rapid industrialization, population growth, and the declining value of

agricultural products driving livelihood and land use change, which exposes increasing numbers of people to flooding.

The strengths and limitations of different types of flood data

Measuring the impacts of natural disasters is the subject of a large literature, wherein there are currently four principal types of weather data used: ground station data, gridded data, satellite data, and reanalysis data. The most basic type of data is the ground station data, which directly observes temperature, precipitation, humidity, barometric pressure, as well as wind speed and direction. Another traditional method is respondents' subjective self-reports of what they consider as an adverse weather shock and its degree of intensity. Both methods have their own advantages. While ground data provides a highly accurate measurement of that exact location's climate, some types of weather data are not available in poor and developing countries, which face more severe constraints to their weather monitoring budget (Burke et al., 2014). Subjective measures have the advantage of being theoretically more precise at the local level than information from spatially aggregated data. However, the subjective measures suffer from both practical and methodological shortcomings (Thomas et al., 2010). They can hardly assess varying severities of weather shocks precisely while also raising issues of endogeneity, especially when incorporated in the vulnerability of the household in question. While global meteorological databases are available, with the exception of the cyclone databases (UNEP/DEWA/GRID-Europe, n.d.) they typically do not have a high resolution.

When comparing different data sources in measuring floods and their impacts, Guiteras, Jina, and Mobarak (2015) compare rainfall data versus flooding data, and self-reports versus satellite images. Their paper makes two key contributions: first, they conclude that objective long-run time series measures of floods will allow us to study human behavioral responses to changes in the distribution of disaster events. Second, they show that rainfall and self-reported exposure are weak proxies for true flood exposure; that measurement error is likely to be correlated with important determinants of socioeconomic outcomes, in particular mean exposure to floods.

To circumvent these weaknesses, we use an external long-run time series measures of floods based on satellite image data. Additionally, as the employed surveys do not

refer directly to flood impacts, we avoid endogeneity issues related to the subjective exaggeration of the floods' impacts.

2.2 METHODOLOGY

This research uses a rich household dataset collected within the framework of the project "DFG-FOR 756: Vulnerability to Poverty in Southeast Asia". This data source is merged with an external flood data set retrieved from daily satellite MODIS Flood Water image (MFW). We reconstruct the flood areas using Geographical Information Systems (GIS) and using Google Earth to draw neighbourhoods of villages. Then we treat satellite images as a measure of floodwater coverage in our villages. Linking these data sources with a panel household data in Thailand and Vietnam allows us to estimate the impact of varying flooding intensities on the array of agricultural outcomes in a panel regression setup. The following sections will describe our data sources and estimation approach in more detail.

2.2.1 Household data

In line with the overall objective of the project "DFG-FOR 756: Vulnerability to Poverty in Southeast Asia", the target population comprised rural households, which are poor or vulnerable to poverty. Six provinces of Vietnam and Thailand were chooses for such research on vulnerability. These include three provinces in Northeast Thailand, namely Buri Ram, Ubon Ratchathani and Nakhon Phanom, and three provinces from the northern central coast and western highlands in Vietnam, namely Ha Tinh, Thua Thien Hue and Dac Lac (see the map of study area in Appendix Figure B.1). These six provinces have experience with high rates of economic growth and success in poverty reduction, but they also suffered from various types of shocks. Among those, weather shocks such as floods and drought are considered as main factor make them vulnerable to poverty.

In this study, we use a panel data covers of 4,400 rural households interviewed in 2007, 2008, 2010 and 2013. The sampling procedure applied was a three-stage cluster sampling with explicit strata for agro-ecological zones in Vietnam and implicit stratification in Thailand. A majority of the households in all six provinces are engaging in agriculture activities, informal self-employment, and off-farm employment. The attrition rate over the four-year panel is around 5%, we are able to include around 4000 households in the main specification sample. This data set contains multiple topic about socio-economic including demographic, health, educational achievements, economic activities, agricultural activities, shocks and risks, employment, financial activities, assets and housing conditions of the sampled households. The survey also includes a section for

village heads, which provides fundamental information of the villages. A full list of the relevant variables as well as their definitions may be found in Appendix Table A2.1.

In order to study how flood shocks impact on agriculture production, we base our research on knowledge from the literature, and the advantages of household surveys, as well as surveys of village heads, so as to build variable groups of control. Researchers often examine the determinants of agricultural production and productivity through analysing various factors. (Challa & Tilahun, 2014) make use of the socio-culture factors and economic factors. (Olujenyo, 2008), based on the Cobb Douglas production function, divides his control variables into labour input and capital input. (Pender & Gebremedhin, 2008) build their crop production model by assuming that crop production is a function of several group input controls such as: labour, oxen power, fertilizer, seeds used, the land management practices used, the 'natural capital' of the plot and the presence of land investments, the tenure characteristics of the plot, human capital, access to agricultural extension services, and the agro-ecological factors that determine local productivity.

In our research, we assume that agricultural outcomes are determined by the household characteristics related to labour inputs such as household size, education of household head, gender of household head, the household economic status such as present value of assets, the access to agriculture extension services because household is living in a main employment agriculture village, or in a village that joins an agriculture program. As a rich dataset, we have sufficient information for control for the land use and management includes area planted for crops (or rice), land tenure, irrigation methods, location of land use, and whether pesticides or fertilizer is used in the land.

In this study, we investigate whether the agricultural vulnerability to flooding depends on the social-economic status of a household, by testing through interactions with some coping strategies such as assets value, and social networks. The social network variable is created from questions in surveys related to informal sources that household can ask for when they suddenly need money. These informal networks consist of relatives, friends, neighbors, pawnshops, informal moneylenders, or village funds.

2.2.2 Flood data

The flood data set and the flood indicators used in this study had been used in two other papers in this dissertation with the same author Le Thi Ngoc Tu. Firstly, we collect the daily satellite MFW images provided by NASA, product version 4.9, which produces daily surface and flood water maps at approximately 250m resolution, in 10x10 degree tiles for South Indochina (Vietnam, Laos, Cambodia, and Thailand). The

principles of MFW is that MFW removes from MODIS Surface Water image as a reference or expected water layer, such that the remaining water is likely to flood. Thus, these MFW only indicate where water has been detected, but cannot measure how deep water was. We use 3-day composite product MFW, which is considered best to limit cloud-shadow issues. We then work on the attribute tables in GIS, the MFW image was processed and coded as the day that image was taken, for example, 2012015 can be understood that image was taken on day 15th in the year 2012. To obtain the measure of flood in one year, we start with doing union all daily MFW into monthly images, afterward, all monthly images were unified into yearly products. Each treated monthly or yearly image gives an estimate surface floodwater during the period, which contains information about the areas and days these areas were flooded

In order to measure the flood indicators for villages, we need to have villages' administrative maps in the study area, which provides the boundary of the research unit. Currently, the administrative maps for rural of Vietnam and Thai land provided by Global Administrative is divided at the smallest unit is the sub-districts (commune). However, as observing flood maps shows us the fact that the impact of flood in different villages in the same sub-district is often different, some villages have flood regularly but others are rarely. It poses us with a task is the need to draw the territory of the villages, even an approximate boundary of the village might help our analysis better than using commune administrative map. The drawing villages' map was based on coordinates of one point belongs to the village and referred to the boundary of commune and image of a village can be seen on Google Earth. Undeniably, the methods of the drawing were used only to ensure that villages are covered but the drawing cannot provide exactly the boundary of actual villages. In order to reduce drawing biasedness, we use the proportion of the village area that has been inundated during the year; the value of this indicator lies between 0 and 1. This measure is the main indicator for analysis.
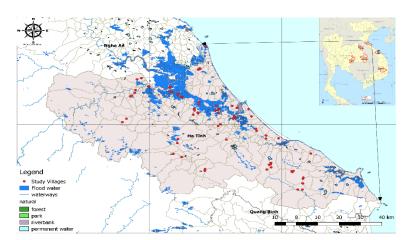
Figure 2.1 : Flooding Map of Ha Tinh Province, from May 2010 to April 2011

Source: Author's calculation

2.2.3 Descriptive statistics of the sample

Table 2.1 below provides summary statistics of the main variables used in the analysis. The sample is pooled across all four waves. On average, the households in the survey have four people in each household. Men head the majority of the families, with only 23% of households being headed by a woman. 88% of the households produce crops and among them 85% produce rice. As the surveys are conducted in poor rural areas, poor households account for 29% of the sample. Overall, approximately 14% of the heads of household have completed his/her secondary school. It is possible that low education is a factor making households more vulnerable to poverty.

On average the annual household income is approximately 7096 USD, with Thailand consistently having a higher annual household income than Vietnam. Although 47% of households in the survey live in villages where agriculture is the main form of employment, the overall total household income from agriculture contributes to only about 30%. The agricultural assets account for approximately 75% of total assets. Examining the agriculture activities, we can see on average a household use of 2.02 hectares for crops, of which 1.22 hectares are used for rice production. 78% of households have their own land, and 96% of them use it for agricultural purposes such as farming, aquaculture or gardening. Additionally, 76% use the land for crop production. The villages where agriculture is the main employment account for 47%, and 37% of villages primarily producing rice. To strengthen the competitiveness of farmers, some agriculture programs are offered. For example, Thailand has the OTOP program and Vietnam has the 135 and 147 program.[5] 32% of villages in the survey participate in at least one of these programs.

42

Table 2.1: Descriptive statistics of the sample

	Mean	SD	Min	Max
Household size	4.09	1.75	0.00	19.00
Head education (Secondary completed 1/0)	0.14	0.35	0.00	1.00
Poor household (1/0)	0.29	0.45	0.00	1.00
Female head (1/0)	0.23	0.42	0.00	1.00
Household produce crops (1/0)	0.88	0.32	0.00	1.00
Household produce rice (1/0)	0.85	0.36	0.00	1.00
Household annual income	7096.73	8013.53	-1876.12	46340.16
Household annual income per capita	1934.15	2319.83	-475.27	13919.56
Household annual crop income	1432.53	3083.42	-3426.33	18328.16
Household total present value of assets	5344.69	12813.41	0.00	777388.25
Household total present value of agriculture assets	3994.45	9511.54	0.00	218075.41
Household annual rice production, in tones	2.56	3.38	0.00	17.99
Household rice productivity (tone/ha)	3.37	4.43	0.01	15.90
Household total crop's area planted (ha)	2.02	28.26	0.00	2627.25
Household total Rice's area planted (ha)	1.22	10.61	0.00	1050.00
Land Tenure (1= household owned)	0.78	0.37	0.00	1.00
Land in the same village (1/0)	0.90	0.28	0.00	1.00
Land mainly use for agriculture purpose (1/0)	0.96	0.19	0.00	1.00
Land mainly use for crops (1/0)	0.76	0.43	0.00	1.00
Agriculture Village (1/0)	0.47	0.50	0.00	1.00
Rice Village (1/0)	0.37	0.48	0.00	1.00
Village participates in agriculture program (1/0)	0.32	0.47	0.00	1.00
Observations	15991			
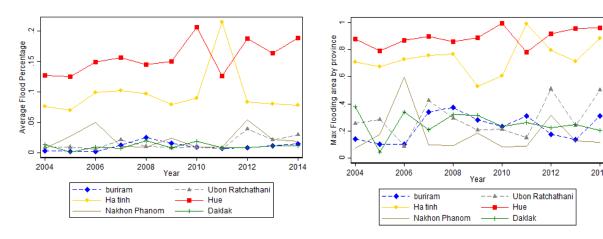
Notes: consumption and income variables have been converted to 2005 USD.

Source: Sample of panel household data 2007, 2008, 2010, 2013; author's calculation.

The Figure 2.2 shows the average proportion of each village floods per year by province. The two most affected provinces are Hatinh and Hue in Vietnam, which continuously exhibited larger average flood levels; the two least affected provinces are Buriram in Thailand and Daklak in Vietnam. While Figure 2.3 shows the maximum of village floodwater area per year by province. The most affected villages in Hue province, Vietnam experience between 80 – 99% of floodwater area. The variation of the maximum floodwater areas fluctuates throughout the year, but the most affected provinces have large floodwater in every year.

Figure 2.2: The mean of each village floodwater area per year, by province

Figure 2.3: The maximum of village floodwater area per year, by province

Flood data of 440 villages in 10 years.

Source: author's calculations.

2.2.4 Empirical strategy

The effects of floods on agricultural production are analysed using a three-part regression setup. First, we examine the direct effects of floods on agriculture outcomes. Second, we investigate the agricultural vulnerability to floods. And third, we study the role of coping strategies to flood shocks. For agriculture production, we focus on crops, livestock, and hunting, which are the main economic activities for rural households in Southeast Asia. Specific attention is given to rice production by analysing rice productivity per hectare. The baseline specifications for each part may be found below:

$$A_{hvt} = \beta_0 + \alpha_1 F_{vt} + \beta_1 H_{hvt} + \beta_2 L_{hvt} + \delta_p + \rho_t + \varepsilon_{hvt} \ (1),$$

Where A_{hvt} denotes the outcomes of agriculture production for each household h, living in village v in year t. The outcome A_{hvt} is measured in different ways, namely: incomes, expenditures, rice productivity measured in tonnes per hectare. Income and expenditure variables are logged before analysis.

44

F_{vt} represents the flood indicator, by which the average of the proportion of a village's area that has been covered by floodwater in the previous year and the year of survey. F_{vt} is a continuous value from 0 to 1. The average flood of two consecutive years is analyzed instead of floods in the current year, due to planting and harvesting seasons.

We assume that agricultural outcomes are determined by the household characteristics (H_{hvt}) related to labor inputs such as household size, education of household head, gender of household head, the household economic status such as present value of assets (lagged by one survey wave to avoid capturing the direct effects of flood on household assets), whether the household produces any crops or rice, the access to agriculture extension services because household is living in a main employment agriculture village, or in a village that joins an agriculture program. The land use and management (L_{hvt}) includes the area planted for crops (or rice), land tenure, irrigation methods, location of land use, whether pesticides or fertilizer are used in the land.

δ_p and ρ_t are the full set of province and wave fixed-effects to account for unobserved differences between provinces and surveys years. The use of long-term panel data with province and wave fixed effects provides a feasible way to protect incomes and consumption estimates from time-invariant unobserved heterogeneity across localities. We estimate this effect by assuming that the remaining variation in flood levels across villages between years is independent of the unobserved heterogeneities in agricultural production of the households. ε_{hvt} is the error term with standard errors clustered at the village level.[6] The estimate of α_1 gives the effect of floods on agricultural outcomes from having no flood (F_{vt} =0) to being covered 100% by floodwater (F_{vt} =1).

Vulnerability, broadly defined as the potential for loss, is an essential concept in hazard research, and is central to the development of hazard mitigation strategies at the local, national and international level (Cutter, 1996). There are subtle yet complex differences in regard to where vulnerability is placed in the conceptual 'chain of events' (James Lewis, 1999), or where authors seem to refer to vulnerability as an outcome (Downing et al., 1999): 'the degree of loss resulting from a potentially damaging phenomenon'. While (Neil Adger, 1999) provides a similar definition, 'the exposure of

groups or individuals to stress as a result of social and environmental change, where stress refers to unexpected changes and disruption to livelihoods'. (Winser et al., 2005) define vulnerability as 'characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of natural hazards'. In most papers on vulnerability to floods, which focus on the household or individual level, the most vulnerable groups are low-income peoples, migrants, those without insurance or financial reserves, the elderly, and the infirm (Few, 2003). While some authors show the connection between poverty and vulnerability (Tran et al., 2008), others like (McElwee et al., 2017) conclude that poverty alone cannot explain flood vulnerability.

In order to classify the above arguments, we entered poor households and female-headed households into analysis. We investigate the differences of effects on different household groups by using the model (1), and add the interaction term $\alpha_2 F_{vt} * V_{hvt}$, which shows the effect of floods on the studied group, where V_{hvt} denotes the group of household such as poor households, or households headed by a woman. The coefficient of interest is α_2, i.e. $(\alpha_1 + \alpha_2)$. Interpretation of α_2 will depend on what outcome is used. For instance, if the outcome is income, then a negative coefficient would indicate greater vulnerability; but if outcome is expenditure then positive coefficient shows greater vulnerability. The sum of two coefficients $(\alpha_1 + \alpha_2)$ shows the effect of floods on the outcomes for studied groups.

The capacity to cope is seen as a key component of flood mitigation at the household level. Following the previous studies of coping mechanisms, people experiencing flood risk may take action through physical means to prevent the spread and penetration of floodwaters and to reduce negative effects of flood through actions such as livelihood diversification, relocation of belongings, and seeking support from the community. (Morrow, 1999) categorizes coping strategies with economic and material resources, human or personal resources (such as education), family and social resources (such as networks of reciprocity), and political resources (such as power and autonomy). The connections between vulnerability and the ownership of a range of assets are highlighted by authors like (Moser, 1998), who say: "The more assets people have, the less vulnerable they are, and the greater the erosion of people's assets, the greater their insecurity." Moser identifies important assets such as labor, housing, social and economic infrastructure, household relations, and social capital.

46

Within the scope of this study, we investigate the role of two informal resources for coping methods that are commonly in rural southeast Asia. The first is the household's agriculture assets, which is lagged by one survey wave to avoid capturing direct effects of the flood on assets. The second is the social network that the household can ask if they suddenly need money. Further, we use the same model (1) and add the interaction term $\alpha_3 F_{vt} * C_{hvt}$, in which C_{hvt} indicates the set of coping mechanisms. The coefficient of interest is $\alpha_3, (\alpha_1 + \alpha_3)$. A negative coefficient α_3 would indicate that a coping strategy reduces vulnerability to flood in term of cost production, but it would indicate an exacerbation of vulnerability in term of productivity. The sum of coefficients $(\alpha_1 + \alpha_3)$ shows the effect of floods on the outcomes if a household has one prevention strategy to cope with flood shock; therefore α_1 will be the effect of floods on a household that does not have a coping strategy.

2.3 FINDINGS

This section of the paper presents the empirical results of our analysis. We use the proportion of floodwater area in villages as the main indicator of flood. First, we categorize agriculture production into two separate parts: expenditures and incomes, in order to analyze the effects of floods on various aspects of agriculture activities. Second, we investigate the vulnerability of different group households to floods. Third, we examine various coping strategies in households. Moreover, as robust checks, we run separate regressions for two alternative transformations for income variables, and two indicators of floods. All the results shown use heteroscedasticity robust standard errors clustered at the village level.

2.3.1 The effects of floods on agriculture production

Table 2.2 and Table 2.3 show that floodwater increases expenditure on crops production and in particular, rice production. Making a comparison between two villages, one of which is not affected at all while the other village is covered totally by floodwater, the expenditure for crops or rice production is about double for the flooded village (column 1), likely because farmers have to repeat all production stages.

Table 2.2 displays the relationship between floodwater and expenditure for crops. In general, floods increase significantly all kinds of expenses, except expenditure for hired labor. We see the heaviest impacts on machinery and irrigation. If a village is covered across 100% of its area, then the expenditure for using machine will be triple over the normal cost (324% in column 2) and increase 160% in the cost for irrigation (in

column 7). It is likely that farmers have to pay for pumping water out of the field and using machinery to rework the farmland after flood, or else they have to contribute finance for repairing canal systems that are damaged by flooding. Recovery from flood damage also increases the cost of seeding 107% (4), fertilizer 133% (5), and pesticides 166% (6). In total, floodwater increase crop expenditure roughly 119% (1). The expenditure for hired labor only increase lightly. This phenomenon can be explained because households in rural areas mainly use in-house human resources for their agriculture production. In addition, we can see the negative relationship between householdsize with labor expense. Whereas other relations with household size are positive, since household agriculture scale is likely positively correlated with household size.

Table 2.2: The relationship between floodwater and expenditure for crops production

	(1) Total	(2) Machine	(3) Labor	(4) Seed	(5) Fertilizer	(6) Pesticides	(7) Irrigation
Flood	1.19**	3.24***	0.18	1.07***	1.33***	1.66***	1.60***
	(4.28)	(6.95)	(0.48)	(3.77)	(4.48)	(5.40)	(4.72)
Observations	9833	9833	9833	9833	9833	9833	9833
Adjusted R2	0.314	0.202	0.334	0.202	0.270	0.338	0.211
Wave- FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province- FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Dependent variables: (1) Log of total household expenditure for crops production, (2) Log of household expenditure for machine use (3) Log of household expenditure for hired labor, (4) Log of household expenditure for seed (5) Log of household expenditure for fertilizer (6) Log of household expenditure for pesticides use (7) Log of household expenditure for irrigation.

Other controls: Household variables, Land use and management variables, village variables.

Source: Author's calculations. (The detail result table is provided in Appendix A2.3).

Looking at Table 2.3 we see a similar picture for rice production. Floods increase the cost per hectare of all items, including hired labor costs. Since rice production is different from other crops, households need to hire labor for transplanting or harvesting in time of season. Compared with non-affected villages, households living in a village where 100% of its area is flooded have a significantly higher (by 93%) total expenditure for rice production (1), in which costs for machine increases 315% (2), cost, cost for hired labor increases 81% (3), cost for seeding increases 95% (4), costs for

fertilizer and pesticides increase 105% (5) and 128% (6) respectively, and cost for irrigation increases 222%.

Examining other control variables, we can see that farmers in villages that are mainly agricultural or engaged in rice production invest more money in production. The villages that participate in an agricultural project show a positive benefit in reducing the costs for farmers in terms of fertilizer use, pesticides, and irrigation. As a result, this reduces the total cost around 8% in comparison with villages that do not participate in a project. (The full result table is in Appendix Table A2.3).

Table 2.3: The relationship between floodwater and expenditure for rice production

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Total	Machine	Labor	Seeds	Fertilizer	Pesticides	Irrigation
Flood	0.93***	3.15***	0.81	0.95**	1.05***	1.28***	2.22***
	(3.47)	(5.52)	(1.95)	(2.89)	(3.77)	(4.68)	(4.19)
Observations	8185	8185	8185	8185	8185	8185	8185
Adjusted R2	0.589	0.179	0.260	0.572	0.395	0.613	0.248
Wave- FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province- FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Dependent variables: (1) Log of total household expenditure for rice production per hectare, (2) Log of household expenditure for machine use in rice production per hectare, (3) Log of household expenditure for seed use in rice production per hectare, (4) Log of household expenditure for hired labor in rice production per hectare, (5) Log of household expenditure for irrigation in rice production per hectare, (6) Log of household expenditure for pesticides use in rice production per hectare, (7) Log of household expenditure for fertilizer use in rice production per hectare.

Other controls: Household variables, Land use and management variables, village variables.

Source: Author's calculations (The detail result table is provided in Appendix A2.4).

Table 2.4 shows the results for the relationship between floodwater and agriculture outcomes, including crop income, livestock income, hunting and aquaculture income, rice income per hectare and rice productivity measure by ton per hectare. The results show that floodwater do not always have a negative effect on agriculture outcomes. Although floodwater can reduce incomes that are dependent on natural sources such as crops income in column (1), livestock income in column (2), and hunting income in column (3), it is possible that floodwater can bring benefits to rice production by increasing the rice productivity in columns (5) and (6).

The floodwater variable is measured as the average of village floodwater proposition in two consecutive years. The value is from 0 to 1, with 0 signifying that the village had no floodwater and 1 meaning that everywhere in the village was covered by floodwater at some points during two years. The results can be explained as follows: village A is not affected and village B is covered around 100% of its area; assuming all other conditions are similar, a household in village B has crops income 26.4% lower, livestock income 41.5% lower and hunting income 103% lower. However, rice grows better in village B with 53.6% higher productivity, equivalent to 2.6 tonne per hectare on average, which then increases rice income by 21 %.

Table 2.4: The relationship between floodwater and agriculture outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
	Crop Income	Livestock Income	Hunting Income	Rice Income	Rice Productivity	Rice Productivity (tone/ha)
Flood	-0.264	-0.415	-1.030[*]	0.210	0.536[***]	2.615[***]
	(-1.25)	(-0.75)	(-2.36)	(1.15)	(6.15)	(5.53)
Observations	7445	7533	9024	6384	8475	8475
Adjusted R2	0.190	0.142	0.162	0.517	0.606	0.517
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Dependent variables: (1) Log of household crop income, (2) Log of household livestock income, (3) Log of household hunting and aquaculture income, (4) Log of household rice income per hectare, (5) Log of household rice productivity (tonne per hectare), (6) Household rice productivity (tonne per hectare).

Other controls: Household variables, Land use and management variables, village variables.

Source: Author's calculations. (The detail result table is provided in).

Examining other control variables, we see that agriculture assets (lagged one survey wave) have a positive relationship with crop income and livestock income, but have a negative correlation with hunting income. Perhaps households that produce crops and livestock invest more in agriculture assets, while households that hunt and fish rely on available natural resources. This might be an added explanation for a significant bigger negative effect of floods on hunting income. Households that own land for

cultivation generally have better crop production. Households that depend on rain for their irrigation have worse rice production outcomes, whereas households that use mechanic irrigation have better crop outcomes. Participating in an agricultural program does not bring a clear benefit for agricultural production.

(OECD, 2017) reviews the prospects and challenges facing the agricultural sector in Southeast Asia over the next decade. Comparing contextual indicators for Thailand and Vietnam, we see that Thailand has a better economic background than Vietnam in many aspects. GDP per capita two time higher than Vietnam (Thailand: 5815 USD, Vietnam: 2111), and nearly three-time higher agricultural land per capita than Vietnam (Thailand: 0.33 ha, Vietnam 0.12 ha), while freshwater resources per capita in Vietnam are higher than in Thailand (Vietnam: 4.000 m^3, Thailand: 3,300 m^3). Productivity improvements are also interesting case in Thailand: the agricultural share of employment fell in Thailand even as its share of GDP rose over the period. In addition, Thailand also scores above average for the relative strengths of the region as a whole, which include aspects of economy-wide policy settings such as the broader macroeconomic environment and its structure (related to governance macro fiscal and monetary policy settings), labor market functioning and levels of human capital, and relatively abundant water resources. With all these above advantage, does Thailand cope with floods better than Vietnam? To versify this question, we add Thailand vs Vietnam into the analysis. Since rice is centered of agricultural production in Southeast Asia, accounting for a greater share of gross production value than any other single commodity. In addition, for a precise comparison purpose, we use rice production for analysis.

Table 2.5 presents the relationship between floodwater and rice production for Thailand and Vietnam. Results in Row (1) are the effects of floodwater on rice production in Vietnam. The results in Row (2) are the differences in the effects of flood on rice production in Thailand compared with Vietnam. Relative to Vietnam, generally speaking, coefficients in Row (3) reaffirm that Thailand has a better rice production performance, showing through higher rice productivity and lower costs for almost rice production expenditures except labor expense. However, regarding to flood impacts, Row (2) shows that Thailand has only advantages in reducing costs of damage, especially costs for machine use, but these advantages are not promoted in rice productivity.

Table 2.2: Flood and Rice production: Thailand vs Vietnam

	Productivity (logged)	Productivity (tone/ha)	Total Expense	Machine Expense	Labor Expense	Seeds Expense	Fertilizer Expense	Pesticides Expense	Irrigation Expense
(1) Flood	0.553***	2.643***	0.976***	3.329***	0.878*	0.994**	1.125***	1.349***	2.281***
	(6.13)	(5.38)	(3.44)	(5.50)	(2.03)	(2.88)	(3.83)	(4.68)	(4.07)
(2) Flood* Thailand	-0.324	-0.530	-0.814	-3.402*	-1.287	-0.780	-1.362	-1.298	-1.258
	(-0.89)	(-0.38)	(-1.51)	(-2.54)	(-0.94)	(-0.78)	(-1.93)	(-1.44)	(-1.41)
(3) Thailand	0.144**	0.199	-0.923***	-0.397*	1.931***	-4.833***	-1.319***	-3.625***	-0.850***
	(3.04)	(0.81)	(-15.57)	(-2.27)	(12.64)	(-36.49)	(-15.83)	(-29.37)	(-4.76)
Observations	8475	8475	8185	8185	8185	8185	8185	8185	8185
Adjusted R2	0.606	0.517	0.589	0.180	0.260	0.572	0.395	0.613	0.248
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Dependent variables: Rice Productivity, Rice Expenditures per hectare.

Source: Author's calculations.

2.3.2 Vulnerability to floods

Table 2.6 and Table 2.7 show the vulnerability of poor households and female-headed households to floods in agriculture production. In some studies, these groups are considered as groups more vulnerable to natural disasters; however, in this research we see that they are not always vulnerable, as it depends on the items we study and the way that we measure it.

Analyzing the interaction term 'Flood*Poor' in column (1) of the Table 2.6, we see that poor household groups are less vulnerable to floods; meaning non-poor household groups are more vulnerable. This finding can be partly explained by looking at the coefficient of 'Poor' in column (2). Poor households have significantly less investment on crop production then they have on lower crop incomes. Therefore, they are less likely to have damage compared with a non-poor household that has similar planted area and other agriculture conditions. However poor people often rely on available natural sources, such as hunting, gathering and fishing, which are heavily influenced by floods. Thus, poor households are significantly more affected in term of their income. Comparing two households living in the same village where 10% area is covered by flood,.a non-poor household has about a 9.67% decrease in hunting income (4) due to flood effect, while a poor household has a 22.08% decrease.

Interaction terms in column (5), (6) and (7) are results for rice production. We see a significant difference between poor and non-poor households in their impacts of floodwater on monetary measures such as income and expenditure, (5) and (6). However, almost no different effect on rice productivity is seen for two groups (7). These findings may suggest a hypothesis that vulnerability will be greater if it is measured in monetary value rather than when it is measured on the basis of quantity.

Table 2.7 shows the relationship between flood and female headed households in agriculture production. In general, the second row for interaction term 'Flood*Female head' presents no significant difference between a family headed by a man or by a woman in term of a floods impact on agriculture production; especially in rice production. The coefficients are very small and not significant.

Table 2.3: The relationship between flood and poor households in agriculture production

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Crop Income	Crops Expense	Livestock Income	Hunting Income	Rice Income	Rice Expense	Rice Productivity
Flood	-0.658**	1.005***	-0.875	-0.967*	0.0528	0.702**	0.486***
	(-2.85)	(3.60)	(-1.57)	(-2.07)	(0.36)	(2.99)	(5.95)
Flood*Poor	0.955**	0.571*	1.125*	-1.241***	0.474*	0.773***	0.095
	(3.18)	(2.22)	(2.53)	(-3.42)	(2.00)	(3.89)	(1.10)
Poor (1/0)	-0.986***	-0.170***	-1.219***	-0.0639	-0.428***	-0.107*	-0.132***
	(-20.35)	(-3.93)	(-15.00)	(-0.94)	(-11.42)	(-2.43)	(-8.71)
Observations	7445	9833	7975	9555	6785	8185	8475
Adjusted R2	0.248	0.316	0.169	0.150	0.540	0.590	0.611
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^{*} p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$.

Dependent variables: (1) Log of household crop income, (2) Log of total household expenditure for crops production, (3) Log of household livestock income, (4) Log of household hunting and aquaculture income, (5) Log of household rice income per hectare, (6) Log of total household expenditure for rice production per hectare, (7) Log of household rice productivity (ton per hectare).

Other controls: Household variables, Land use and management variables, village variables.

Source: Authors calculations

Table 2.4: The relationship between flood and female-headed households in agriculture production

	(1) Crop Income	(2) Crops Expense	(3) Livestock Income	(4) Hunting Income	(5) Rice Income	(6) Rice Expense	(7) Rice Productivity
Flood	-0.262	1.206***	-0.401	-1.169*	0.303	0.947***	0.551***
	(-1.21)	(4.42)	(-0.79)	(-2.46)	(1.89)	(3.48)	(6.24)
Flood* Female head	0.030	-0.051	0.189	-0.603	-0.291	-0.082	-0.095
	(0.13)	(-0.12)	(0.26)	(-1.33)	(-1.53)	(-0.46)	(-0.90)
Female head	-0.207***	-0.221***	-0.443***	-0.261***	-0.020	0.056	-0.003
	(-4.11)	(-4.49)	(-4.00)	(-3.41)	(-0.50)	(1.54)	(-0.16)
Observations	7445	9833	7975	9555	6785	8185	8475
Adjusted R2	0.192	0.317	0.144	0.151	0.528	0.589	0.606
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Dependent variables: (1) Log of household crop income, (2) Log of total household expenditure for crops production, (3) Log of household livestock income, (4) Log of household hunting and aquaculture income, (5) Log of household rice income per hectare, (6) Log of total household expenditure for rice production per hectare, (7) Log of household rice productivity (ton per hectare).

Other controls: Household variables, Land use and management variables, village variables.

Source: Author's calculations.

2.3.3 The role of coping strategies

is modeled by interacting the floodwater with households' lagged agricultural assets. We use the present value of assets, which is lagged by one survey wave to avoid capturing the direct effects of the floodwater on assets. The results show that rich-agriculture assets families are coping with flood shock better than poor-agriculture assets family, assets reduce expense for crops and expense for rice production in term of flooding impact. For two households living in the same village, the household that has 10% higher present value of agriculture assets can save their costs for crops and rice due to flood shock 2.4% and 1.82% respectively; in comparison with the lower agriculture asset family. However, according to the results in column (3), assets play a weak role in rice productivity, as the interaction term is small and insignificant.

Table 2.5: Household assets as coping strategy to flood shock

	(1)	(2)	(3)
	Crops Expense	Rice Expense	Rice Productivity
Flood	2.566^{***}	1.901^{**}	0.560^{**}
	(4.95)	(3.07)	(2.71)
Flood *Assets	-0.240^{**}	-0.182^{**}	-0.004
	(-3.21)	(-2.59)	(-0.15)
Assets	0.202^{***}	0.0733^{***}	-0.00426
	(13.31)	(3.57)	(-0.99)
Observations	9833	7705	8475
Adjusted R2	0.316	0.576	0.606
Wave –FE	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes
Other controls	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^{*} p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$.

Dependent variables: (1) Log of total household expenditure for crops production, (2) Log of total household expenditure for rice production per hectare, (3) Log of household rice productivity (tonne per hectare).

Other controls: Household variables, Land use and management variables, village variables.

Source: Author's calculations.

Table 2.9 shows the role of social networks in providing a coping strategy to flood shock. The interaction term 'Flood*Social network' in column (1) indicates an insignificant role of social network in crop production in general, but such networks play a small role in reducing expenditure for rice production in column (2). Column (3) shows a negative coefficient of interaction. In flood events, households that have support from social networks are those that have lower rice productivity. However, these results should be seen as indicative rather than causal. Since households need help, it is likely that households are vulnerable to shocks.

Table 2.6: Social networks as coping strategy to flood shock

	(1)	(2)	(3)
	Crops Expense	Rice Expense	Rice Productivity
Flood	1.020**	0.889**	0.651***
	(2.85)	(2.77)	(6.36)
Flood*Social network	0.255	-0.039	-0.162
	(0.94)	(-0.23)	(-1.69)
Social network (1/0)	-0.0777*	-0.0470	-0.00374
	(-2.41)	(-1.45)	(-0.27)
Observations	9833	7710	8475
Adjusted R2	0.314	0.573	0.606
Wave –FE	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes
Other controls	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^* p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$.

Dependent variables: (1) Log of total household expenditure for crops production, (2) Log of total household expenditure for rice production per hectare, (3) Log of household rice productivity (ton per hectare).

Other controls: Household variables, Land use and management variables, village variables.

Source: Author's calculations.

2.4 Robustness check

2.4.1 Working with negative incomes

Working with agriculture incomes we often see negative values, which happens when production costs are higher than revenue, the household data set used in this study is no exception. In the household data, negative values comprise about 15% of observations of crops income, 22.5% of observations of livestock income, 4% of observations of hunting income, and 11% of observations of rice income. We understand that studying weather impacts can sometimes tell meaningful stories about negative incomes; we want to know if we miss any those stories, therefore we compare the results of different methods of transformation: log transformation and inverse hyperbolic sine transformation.

In the Table 2.10, the results show similar effects for both transformation methods. Log transformation is the most common used in studies on income, because it provides an easy interpretation for the coefficient; however its disadvantage is that it ignores negative values. There are several alternative methods for working with negative incomes; one of those methods is moving the whole distribution to the right by adding an amount to make all observations positive before performing the log transformation. This method has its own advantage, which is that it is easy to interpret. However, this method is very sensitive when different amounts are added. An additional method that is preferred by some researchers is cube root transformation, which can preserve the negative sign of value. Therefore, this transformation takes all values into account. Its disadvantage is a complicated interpretation for coefficients. It is good news that the inverse hyperbolic sine method can avoid the disadvantages mentioned, and this method can transform all values as well as providing an understandable interpretation for coefficients. The formula is IHS $(y) = \text{sign}(y) * \ln(y+(y^2+1)^{1/2})$; except for very small values of y, the inverse sine is approximately equal to $\ln(2y)$ or $\ln(2) + \log(y)$, and so it can be interpreted in exactly the same way as a standard logarithmic dependent variable. [7]

Table 2.7: Log transform Versus Inverse Hyperbolic Sine transform

	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
	Crop Income	Crop Income IHS	Livestock Income	Livestock Income IHS	Rice Income	Rice Income IHS
Flood	-0.264	-0.188	-0.415	-0.339	0.210	0.247
	(-1.25)	(-0.88)	(-0.75)	(-0.65)	(1.15)	(1.40)
Observations	7445	8950	7533	9286	6384	7244
Adjusted R2	0.190	0.166	0.143	0.118	0.517	0.469
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes
Other	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^* p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$.

Dependent variables:

(1a) Log of total household income from crops production, (1b) inverse hyperbolic sine transformed of total household income from crops production; (2a) Log of total household income from livestock, (2b) inverse hyperbolic sine transformed of total household income from livestock, (3a) Log of household income from rice production per hectare, (3b) inverse hyperbolic sine transformed of household income from rice production per hectare.

Other controls: Household variables, Land use and management variables, village variables.

Source: Author's calculations.

2.4.2 Alternative flood indicators

Table 2.11 shows the relationship between flooding days and agriculture outcomes; these regressions repeat regressions in Table 2.2, but with replacement of flooding days for floodwater proportion in a village. These results tell the same story as those in Table 2.2: namely that floods bring negative effects to incomes from crops, livestock, and hunting, but floods have a positive effect on rice production. The difference between Table 2.2 and Table 2.11 is that Table 2.2 measures the proportion of a village is covered by floodwater in one year, while Table 2.11 counts the number of days a village has floodwater. The results in Table 2.11 can be interpreted as follows: two households have similar conditions living in two different villages. Village A has no flood and village B has 175 flooding days in one year (maximum of the variable *flooding days)*. The household in village B has a lower income from crops, livestock,

and hunting; 56%, 101% and 121% respectively. Rice production in village B is better than in village A, with 53.2% higher productivity equivalent to 2.67 tonnes per hectare.

Table 2.8: The relationship between number of flooding days and agriculture outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
	Crop Income	Livestock Income	Hunting Income	Rice Income	Rice Productivity	Rice Productivity (tonnes/ha)
Flooding days	-0.0032	-0.0058	-0.0069	0.001	0.003***	0.0153***
	(-1.68)	(-1.37)	(-1.94)	(0.99)	(4.27)	(3.46)
Observations	7445	7533	9024	6384	8475	8475
Adjusted R2	0.191	0.143	0.160	0.517	0.604	0.514
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^{*} p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$

Dependent variables: (1) Log of household crop income, (2) Log of household livestock income, (3) Log of household hunting and aquaculture income, (4) Log of household rice income per hectare, (5) Log of household rice productivity (ton per hectare), (6) Household rice productivity (tonnes per hectare).

Other controls: Household variables, Land use and management variables, village variables.

Source: Author's calculations.

The results presented above demonstrate clearly that rice is growing better in flooding villages; this finding is reasonable since rice needs water to grow, while some flooding bring silts for the soil. Further, we ask a question "whether it suffers if there is too much flooding". We try to answer this inquiry by adding the variation of floodwater into analysis. The variation of floodwater is measure by the deviation of floodwater area in current year with the average floodwater area during last five years. Table 2.12 shows both the results of the direct effect of floodwater on outcomes and the effect of flood variations. Overall, flood variation has a small effect on hunting and livestock incomes. However, variation of floodwater has negative impacts on crop and rice incomes: if floodwater area in the current year (the year that outcomes were measured) is one standard deviation larger than normal floodwater area in the same village, the incomes from crops and rice will reduce about 5% and the rice productivity also reduce around

3% equivalent to 0.156 ton per hectare. In an extreme case, if floodwater area in the current year is three standard deviations larger, rice productivity might be reduced 15% equivalent to approximately 0.5 tonnes per hectare.

Table 2.9: The relationship between floodwater variation and agriculture outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
	Crop Income	Livestock Income	Hunting Income	Rice Income	Rice Productivity	Rice Productivity (ton/ha)
Flood	-0.225	-0.320	-0.968*	0.250	0.562***	2.733***
	(-1.05)	(-0.59)	(-2.21)	(1.35)	(6.34)	(5.70)
Floodwater	-0.051	0.027	0.003	-0.052	-0.034	-0.156
variations	(-1.18)	(0.26)	(0.03)	(-1.01)	(-1.38)	(-1.14)
Observations	7445	7533	9024	6384	8475	8475
Adjusted R2	0.190	0.143	0.160	0.518	0.607	0.517
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^{*} p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$.

Dependent variables: (1) Log of household crop income, (2) Log of household livestock income, (3) Log of household hunting and aquaculture income, (4) Log of household rice income per hectare, (5) Log of household rice productivity (ton per hectare), (6) Household rice productivity (ton per hectare).

Other controls: Household variables, Land use and management variables, village variables.

Source: Author's calculations.

However, this result should only be used for reference rather than for a main finding. One of the limitations of this study is that we only have flood data for ten years from 2003 to 2013 because satellite images of floodwater provided by NASA only began in 2002, whereas our household data is from 2007. In order to create a good indicator of flood's variation, we should have a long-time flood dataset of about twenty years or more.

2.4.3 Province-year Fixed effects

Much of the empirical literature has so far assumed flood measures to be exogenous. Despite measurement, objective measures may yield biased estimates. First, the repeated occurrence of floods in an area is likely correlated with the possibility of it occurring in the first place, which may in turn affect the level of incomes and expenditures. Second, households in affected areas have likely adapted to these circumstances by coping strategies or building successful livelihood systems called "living with floods". To relieve that worry, we shall compare households from the same province and the same time, who should face a similar flood trend. We perform a robustness check with province-wave fixed effects to account for changes in living conditions over time in each province.

The results in Table 2.13 give us a very similar result compared with the main findings in Table 2.2. This shows that we can be confident to use the province fixed effects and year fixed effects to control for time-invariant unobserved heterogeneity across locations.

Table 2.10: The relationship between floodwater and agriculture outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
	Crop Income	Livestock Income	Hunting Income	Rice Income	Rice Productivity	Rice Productivity (tone/ha)
Flood	-0.373	-0.292	-0.909*	0.142	0.479***	2.355***
	(-1.72)	(-0.53)	(-2.10)	(0.95)	(6.04)	(5.38)
Observations	7445	7533	9024	6384	8475	8475
Adjusted R2	0.207	0.146	0.174	0.556	0.642	0.555
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province*Wave -FE	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Dependent variables: (1) Log of household crop income, (2) Log of household livestock income, (3) Log of household hunting and aquaculture income, (4) Log of household rice income per hectare, (5) Log of household rice productivity (tone per hectare), (6) Household rice productivity (tone per hectare).

Source: Author's calculations.

2.5 CONCLUSIONS

This study contributes to the existing literature in two significant ways. First, we construct an external data sets on local flood maps obtained from satellite observations to measure floods. This has the advantage of highly precise and objective geographical satellite data. Second, we analyze the effects of the flood on agriculture production by analyzing different aspects of impacts. This gives us a broader view of flood impacts and helps to explain the findings more precisely. Floods can have many negative effects, such as increasing agriculture expenditures and reduce agriculture incomes. On the other hand, floods can also increase rice productivity. Agricultural economists and policy makers can apply these findings in building effective cooperation between farmers with local governments, so as to have sustainable coping strategies to floods, appropriate farming strategies or land use, and on-time planting and harvesting plans, all in order to reduce the costs for re-cultivating crops. Local governments and communities should establish efficient distribution channels for selling agriculture products; the benefits from productivity will bring economic benefits to farmers. This research also sheds light on the concept of *vulnerability;* suggesting that, a group of people become more vulnerable when we measure outcomes with monetary values, but not if we solely measure outcomes by quantity. These findings suggest that perhaps nature treats people equally even in disaster, but some people become more vulnerable when we put them in their socio-economic context. More research is needed to unpack this hypothesis.

NOTES

(1) The German Research Foundation (DFG) in Bonn, Germany in 2006 has awarded a special research unit to the Universities of Hannover, Göttingen and Frankfurt. The subject of the project is the analysis of the role of shocks and risks for the development of poor countries and emerging market economies.

(2) As secondary data for sampling Thailand was available down to the village level, population density and agro-ecological conditions were assumed to be sufficiently homogeneous; sample design for Thailand is kept simple and aimed at obtaining a self-weighting sample. The provinces in Vietnam were purposively selected for the survey and are geographically more diverse than those in Thailand. While Dak Lak province is part of the landlocked Central Highland, Thua Thien-Hue, and Ha Tinh provinces extend from the coast to the mountainous border to Laos. In order to take into account this heterogeneity, strata for the first stages were defined as agro-ecological zones within the three provinces.

(3) For each village, one coordinate was recorded by the interviewers during the village interviews. The coordinates were recorded in decimal degrees (latitude, longitude). For example, the geographical coordinates of the village Yang, sub-district Kham Duan, district Krasang, province Buriam, Thailand is (15.0773638888889, 103.401458333333).

(4) Another limitation of this method is that satellite images of floodwater can only capture the surface of water but cannot measure the depth of water.

(5) The objective of the One Tambon One Product (OTOP) project in Thailand is to support local manufactured products and empower people living in communities to use their skills in manufacturing to improve the quality and marketing of local products. Government agencies and the private sector provide support to the villages to create marketable designs and packages. The Program 135 (P135) was established in 1998 to implement government policies targeting the most vulnerable communities to promote production and access to basic infrastructure, improve education, train local officials, and raise people's awareness for better living standards and quality of life.

(6) The standard errors are clustered at village level due to sampling design. The survey used a three-stage clustered sampling approach. Provinces were targeted, sub-districts were selected with probability proportional to population size (PPS), followed by a simple random PPS sample of two villages from each sampled sub-district. Lastly, households were randomly sampled with implicit stratification by household size. We account for the survey design using sample weights.

(7) IHS $(y) = \text{sign}(y) * \ln(y+(y2+1)1/2)$. This symmetric function is linear around the origin and approximates the logarithm in its right tail. In fact, for large y, this function is simply a vertical displacement of the logarithm: $\ln(y+(y2+1)1/2) \approx \ln(2y) + \ln(y)$.

Appendix A2

Table A 2.1: Variable definitions

Variable	Definition
Agriculture Assets	Household total present value of agriculture asset items
Agriculture land	Dummy variable, takes the value 1 if land is mainly used for agricultural purposes
Agriculture Land Area	Household total agriculture land area (ha)
Agriculture Village	Dummy variable, takes the value 1 if the main employment in the village is agriculture
Area Planted	Household total crop area planted (ha), or households total rice area planted (ha)
Crop Land	Dummy variable, takes the value 1 if land is mainly used to grow crops
Female head	Dummy variable, takes the value 1 for households that are headed by a woman
Flooding days	The number of days in one year that a village has floodwater
Floodwater area	Average of the proportion of a village area that has been covered by floodwater in the previous year and current year
Floodwater variation	standard deviation of this year floodwater area from the average of last 5 year floodwater area
Head education	Categorical variable, which takes values 0-6 0: No education 1: Primary not completed 2: Primary completed 3: Lower secondary completed 4: High school / vocational completed 5: Some college / advanced vocational completed 6: University or higher
Household Assets	Household total present value of asset items
Household crop expenditures	Household total expenditure for all crop production, includes expenditures for machinery, hired labor, seeds and seeding, fertilizer materials, pesticides materials, and irrigation
Household crop income	Household total annual income from crop production
Household hunting income	Household total annual income from fishing, hunting, collecting, or logging activities
Household income	Household total annual income
Household income per capita	Household total annual income per capita
Household livestock income	Household total annual income from livestock

Household produce crops	Households that grow rice, field crops, permanent crops, or forest in the year of study
Household produce rice	Households that grew rice in the year of study
Household rice expenditures	Household total expenditure for rice production, includes expenditures for machinery, hired labor, seeds and seeding, fertilizer materials, pesticides materials, and irrigation
Household rice income	Household total annual income from rice production
Household rice production	Household total rice production in the year of study, in tons
Household rice productivity	Household mean rice productivity, yield in ton per hectare
Household size	Household nucleus size, includes only members of the family who stay in the household for more than 6 months
Land in Village	Dummy variable, takes the value 1 if planted parcel land in the same village
Land Tenure	Dummy variable, takes the value 1 of household owned land
Mechanic Irrigation	Dummy variable, takes the value 1 if the farmer uses mechanic irrigation to grow crops (pipe, tap, pumped from public irrigation canal)
Poor household	Dummy variable, takes the value 1 for poor families that have an income per capita below the poverty line (1.9$ per day)
Rain Irrigation	Dummy variable, takes the value 1 if farmer depends on rain for irrigation to grow crops
Rice Village	Dummy variable, takes the value 1 if main agriculture activity in village is rice production
Use Fertilizer	Dummy variable, takes the value 1 if the farmer spends money on fertilizer to grow crops (or rice)
Use Pesticides	Dummy variable, takes the value 1 if the farmer spends money on pesticides to grow crops (or rice)
Village join agriculture program	Dummy variable, takes the value 1 if the village participates in one of the agricultural programs (OTOP in Thailand, program 135 or 147 in Vietnam)

Notes: Expenditure and income variables have been converted to 2005 USD

Source: Author's calculation

Table A 2.2: The relationship between flood and agriculture outcomes

	(1) Crop Income	(2) Livestock Income	(3) Hunting Income	(4) Rice Income	(5) Rice Productivity	(6) Rice Productivity
Flood	-0.264 (-1.25)	-0.415 (-0.75)	-1.030* (-2.36)	0.210 (1.15)	0.536*** (6.15)	2.615*** (5.53)
Agriculture Assets	0.162*** (13.14)	0.134*** (5.94)	-0.134*** (-8.85)	0.0334*** (3.78)	-0.00444 (-1.11)	-0.0331 (-1.54)
Household size	0.0760*** (6.34)	0.157*** (6.07)	0.142*** (7.62)	0.00878 (0.91)	-0.0157*** (-3.49)	-0.0622* (-2.50)
Head Education	0.0356 (1.68)	0.0362 (0.81)	-0.161*** (-5.34)	0.0286 (1.93)	-0.00307 (-0.45)	-0.0390 (-1.13)
Share working age	0.0819* (2.40)	0.178** (2.76)	0.0739 (1.44)	-0.0322 (-1.10)	-0.0235* (-2.37)	-0.125** (-2.65)
Crop Land (1/0)	0.322*** (5.99)	0.307** (3.11)	0.253*** (3.48)			
Agriculture Village (1/0)	0.409 (1.70)	0.685 (1.50)	0.431 (1.11)			
Village join Agriculture Program (1/0)	0.0384 (0.78)	0.163 (1.58)	0.0343 (0.39)	0.0620 (1.53)	-0.0258 (-1.25)	-0.174 (-1.55)
Village's	-0.0296 (-1.40)	-0.0553 (-1.22)	-0.131** (-3.27)	-0.0555** (-2.67)	-0.0116 (-1.26)	-0.0254 (-0.50)
Area Planted	0.00225** (2.67)					
Land Tenure	0.229*** (3.43)			0.178*** (3.81)	0.0472* (2.13)	0.315* (2.47)
Mechanic Irrigation	0.149* (2.51)			0.116* (2.21)	0.0245 (0.97)	0.235 (1.62)
Rain Irrigation	0.00474 (0.09)			0.0899* (2.10)	-0.0534** (-2.82)	-0.189 (-1.83)
Land in Village	-0.117 (-1.41)			0.00576 (0.10)	0.0302 (1.21)	0.105 (0.85)
Use Pesticides (1/0)	0.370*** (7.09)			0.0474 (1.16)	0.0533** (2.78)	0.403*** (3.80)
Use Fertilizer (1/0)	0.617*** (4.03)			-0.00166 (-0.02)	-0.188*** (-4.99)	-1.028*** (-5.01)
Rice Village (1/0)				-0.478*** (-6.70)	-0.107** (-2.70)	-1.001*** (-3.90)
_cons	4.165*** (12.73)	1.476** (2.86)	3.861*** (9.28)	8.313*** (45.62)	2.411*** (29.47)	9.678*** (21.16)
Observations	7445	7533	9024	6384	8475	8475
Adjusted R2	0.190	0.142	0.162	0.517	0.606	0.517
Wave –FE	yes	yes	yes	yes	yes	yes
Province –FE	yes	yes	yes	yes	yes	yes

OLS regressions. Standard errors, clustered at village level. $^* p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$.

Dependent variables: (1) Log of household crop income, (2) Log of household livestock income, (3) Log of household hunting and aquaculture income, (4) Log of household rice income per hectare, (5) Log of household rice productivity (ton per hectare), (6) Household rice productivity (ton per hectare).

Source: Author's calculations.

Table A 2.3: The relationship between flood and expenditure for crops production

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Total	Machine	Labor	Seed	Fertilizer	Pesticides	Irrigation
Flood	1.191***	3.239***	0.176	1.068***	1.329***	1.661***	1.599***
	(4.28)	(6.95)	(0.48)	(3.77)	(4.48)	(5.40)	(4.72)
Agriculture	0.191***	0.121***	0.156***	0.0854***	0.200***	0.149***	0.120***
Assets	(13.36)	(6.43)	(8.68)	(5.48)	(12.47)	(11.21)	(8.90)
Household	0.0717***	0.0433*	-0.0434*	0.0716***	0.0637***	0.0744***	0.0518***
size	(6.13)	(2.31)	(-2.23)	(4.31)	(4.87)	(4.94)	(3.51)
Head	0.0652***	-0.0208	0.144***	0.0222	0.0394	-0.00935	0.0575*
Education	(3.34)	(-0.66)	(4.28)	(0.74)	(1.72)	(-0.37)	(2.20)
Crop size	1.093***	1.098***	1.180***	0.641***	0.974***	0.669***	0.124
	(4.72)	(4.07)	(5.05)	(3.54)	(4.89)	(6.01)	(1.73)
Agriculture	0.841**	1.015*	0.351	0.0348	0.906***	0.547	-0.135
Village (1/0)	(3.09)	(2.31)	(1.39)	(0.09)	(3.63)	(1.87)	(-0.42)
Village join	-0.0785	-0.0436	-0.101	0.000709	-0.113*	-0.128	-0.414***
Program (1/0)	(-1.61)	(-0.46)	(-1.39)	(0.01)	(-2.05)	(-1.81)	(-4.97)
Constant	3.613***	2.588***	1.832***	0.145	2.596***	-0.324	-0.411
	(12.56)	(5.87)	(6.51)	(0.36)	(9.66)	(-1.08)	(-1.28)
Observations	9833	9833	9833	9833	9833	9833	9833
Adjusted R2	0.314	0.202	0.334	0.202	0.270	0.338	0.211
Wave- FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province- FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Dependent variables: (1) Log of total household expenditure for crops production, (2) Log of household expenditure for machine use in crops production, (3) Log of household expenditure for hired labor in crops production, (4) Log of household expenditure for seed use in crops production, (5) Log of household expenditure for fertilizer use in crops production, (6) Log of household expenditure for pesticides use in crops production, (7) Log of household expenditure for irrigation in crops production.

Source: Author's calculations.

Table A 2.4: The relationship between flood and expenditure for rice production

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Total	Machine	Labor	Seeds	Fertilizer	Pesticides	Irrigation
Flood	0.934***	3.154***	0.812	0.954**	1.055***	1.282***	2.216***
	(3.47)	(5.52)	(1.95)	(2.89)	(3.77)	(4.68)	(4.19)
Agriculture Assets	0.0595**	0.111***	0.0370*	0.0399**	0.0881***	0.0721***	0.0944***
	(3.30)	(5.00)	(2.23)	(2.65)	(4.63)	(4.91)	(6.05)
Head education	0.0237	0.0529	0.0706*	0.0604*	-0.00269	-0.0346	-0.00146
	(1.80)	(1.59)	(2.00)	(2.15)	(-0.13)	(-1.56)	(-0.05)
Household size	-0.0330***	-0.109***	-0.0792***	0.00190	-0.0332**	0.00465	-0.00406
	(-3.55)	(-6.15)	(-4.03)	(0.14)	(-2.90)	(0.35)	(-0.26)
Rice Village	-0.468***	0.388*	0.306*	-1.423***	-0.269***	-0.569***	-0.517**
	(-7.30)	(2.17)	(2.26)	(-9.94)	(-3.59)	(-5.24)	(-2.72)
Village join program	-0.0880*	-0.148	-0.0535	0.0227	-0.0769	-0.0511	-0.313***
	(-2.33)	(-1.47)	(-0.71)	(0.32)	(-1.62)	(-0.77)	(-3.38)
Constant	8.934***	5.739***	3.926***	2.235***	6.671***	2.261***	1.047***
	(79.60)	(25.22)	(21.17)	(12.89)	(45.79)	(14.66)	(4.92)
Observations	8185	8185	8185	8185	8185	8185	8185
Adjusted R2	0.589	0.179	0.260	0.572	0.395	0.613	0.248
Wave- FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province- FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^{*}\,p < 0.05$, $^{**}\,p < 0.01$, $^{***}\,p < 0.001$.

Dependent variables: (1) Log of total household expenditure for rice production per hectare, (2) Log of household expenditure for machine use in rice production per hectare, (3) Log of household expenditure for seed use in rice production per hectare, (4) Log of household expenditure for hired labor in rice production per hectare, (5) Log of household expenditure for irrigation in rice production per hectare, (6) Log of household expenditure for pesticides use in rice production per hectare, (7) Log of household expenditure for fertilizer use in rice production per hectare.

Source: Author's calculations.

3. FLOODS AND HOUSEHOLD WELFARE: EVIDENCE FROM SOUTHEAST ASIA

Abstract: This research uses a rich panel data set of household surveys and external long-term flood data extracted from satellite images to complete a puzzling picture of the effects of floods on household welfare. Floods bring a lot of negative effects to households; the floods reduce household incomes dependent on natural sources, pushing farmers out of the fields to seek extra income from non-agricultural activities. In addition, the floods increase all consumption categories, including health expenditure. All these results are reaffirmed by the finding of a lower household subjective wellbeing score.

3.1 INTRODUCTION

According to the definition of household welfare measures from the World Bank, household welfare can be measured on the monetary dimensions of wellbeing such as income or consumption. Household welfare also can be based on non-monetary dimensions such as health or education, or subjective wellbeing measures or qualitative measures.

Many researchers around the world contribute findings for this field of study from different contexts, different time periods, different methods of welfare measures as well as using different flood indicators, all depending on the availability of data that researchers can assess. All research findings are necessary to create a global picture of the relationship between floods and household welfare. However, we lack research where the relationship between floods and household welfare is examined in multiple dimensions on the same population over time. This study will contribute such a missing piece to the whole picture of literature. In this research, I examine household welfare viewed through a multi-dimensional lens including income compositions, consumption categories, and health expenditure as an indicator of health impact in household, and household subjective wellbeing.

This research aims to answer two research questions: (1) How do floods impact on households in multi-dimensional concept of welfare?"; and (2) "Which channel of insurance mechanism is commonly used and effective in rural households to cope with flood shock?" These questions are addressed by focusing on floods in Vietnam and Thailand using long-time measurement of household welfare, combined with an external flood indicator, which is a measure of local inundation by using satellite floodwater images provided by NASA, the MODIS Near Real Time Global Flood Water (MFW).[1]

The results show that floodwater reduces household incomes dependent on natural sources and pushes farmers out of the fields to seek extra income from non-agricultural activities. On the other hand, floodwater increase all consumption categories, and lays a burden on financial cost for health care on household budgets. Analysis from household subjective wellbeing tells a story of people living in affected villages who are less happy than people living in non-affected villages. I also find that intra-house coping strategies are more commonly used in rural households; however, the scope of the impact of flooding is too large to be coped with at household level.

Measuring household welfare: straight-forward concept, and expanded concept

The World Bank's Living Standards Measurement Study introduces three alternative approaches to the measurement of household welfare. The first approach is the estimation of true indices of welfare; this is conceptually superior in that it relies on a complete set of behavioral equations depicting households' consumption and employment behavior, from which to derive welfare. The second one is the full income approach. And the third approach looks only at household expenditures (Moratti & Natali, 2012).

The true index approach uses observed behavior as ordering references to estimate a measure of welfare. The full income and expenditure use monetary and imputed flows without specific assumptions about preferences. Both methods require deflation of the welfare measure with a price index. Generally, the expenditure method seems to be easier to measure and tends to be less subject to fluctuations than income (Grootaert, 1983).

There are some other components of welfare that have been seen in literature; among those methods, employing an expanded range of human development indices is the most popular approach. These indicators include health, education, nutrition, fertility and infant mortality. However, these methods were not considered much until recent years.

In recent decades, researchers in macro-economic have become aware that GDP does not provide policy-makers with a sufficiently detailed picture of the living conditions that ordinary people experience. Evidence of strong economic growth during the early 2000s, which was amplified by the financial and economic crisis that followed it, is a confirmation that income alone cannot be a good indicator reflecting a true measure of sustainable welfare improvement. A wide range of factors that affect people and their wellbeing is necessary for the credibility and accountability of public policies.

A framework for improvements in measuring the wellbeing of people and households has been developed by the OECD.[2] This framework is built on three distinct domains: material conditions, quality of life and sustainability. Each of these domains includes a number of relevant dimensions: material living conditions (income and wealth, jobs and earnings, housing conditions) and quality of life (health status, work-life balance, education and skills, social connections, civic engagement and governance,

environmental quality, personal security and subjective wellbeing). Sustainability refers to the future wellbeing that determines wellbeing over time through preserving capitals such as natural and economic, human and social (*OECD Guidelines on Measuring Subjective Well-being*, 2013).

The study, (OECD, 2013) "How's Life? Measuring wellbeing", a report of the progress in measuring wellbeinghas covered a range of areas, such as income and wealth, education, environment and subjective wellbeing. This measure reflects a wide range of people's attributes and circumstances; however, it should not be considered as the single all-encompassing measure of people's wellbeing. In measuring overall human wellbeing, subjective wellbeing should be placed alongside measures of non-subjective outcomes, such as income, health, knowledge and skills, safety, environmental quality and social connections.

Flood impacts on household welfare, and coping strategies

Among all kinds of natural disasters, floods are the most common in both developed and developing countries, accounting for approximately 40% of all natural disasters. Asia is the most flood-affected region, accounting for nearly 50% of flood-related fatalities in the last quarter of the 20th century (Jonkman, 2005). The objectives of this literature review section is to summarize the impacts of flood on household welfare in terms of income, consumption, health, and subjective wellbeing.

(Khandker, 2007) examines the impact of floods on household welfare in Bangladesh during 1998, that study finding that flood intensity actually reduced household welfare both in terms of consumption and household non-land assets. Although the effect of flooding on household welfare is significant, the floods had no lasting impact on consumption and assets. This is explained as either due to the ensuing productive crop, or through other available sources including borrowing from micro-credit and assistance programs after floods. Based on a study conducted on the same population after the 1988 flood, (Emdad Haque & Zaman, 1993) found rather that the majority of the households sold their land, livestock, or belongings to reduce the losses due to the flood, and many moved their housing structures, livestock, and family members to safer places. Another study in Bangladesh (Parvin, Shimi, Shaw, & Biswas, 2016) found that the three major coping strategies adopted during the 1998 flood were

reducing expenditure, selling assets, and borrowing, with borrowing being the most important.

(Tran et al., 2008) study flood risk management in Thua Thien Hue, Central Vietnam. They explore the impacts of floods on the economy, environment, and society and try to clarify the rural community's coping mechanism to flood disasters using a mixed methodology. The results show that annual floods bring significant damage to agriculture and aquaculture by destroying crops in the rice field, sweeping away aquaculture products, or ruining fish and shrimp ponds. Despite these negative impacts, the survey revealed that a high percentage of respondents think that floods help to clean the environment. Floods bring alluvium to agricultural land and kill insects and rats. Some respondents even claimed that every 3 years a big flood is needed to refresh the lagoon environment. Many respondents agreed that the production of aquaculture and agriculture increase after a large flood. However, their approach only permitted a subjectively assessment of the effect of floods on agriculture.

Research by (Yasuaki Hijioka, Erda Lin, 2014) indicates that increases in floods and droughts will exacerbate rural poverty in parts of Asia, as a result of negative impacts on the rice crop and resulting increases in food prices. The rising cost of living will in turn have an increasing impact on human health, security, livelihoods, and poverty, with the type and magnitude of impact varying across Asia.

(Bui, Dungey, Nguyen, & Pham, 2014) use the Vietnam Household Living Standard Survey in 2008 to examine the effect of natural disasters on household income, expenditure, poverty and inequality. The results are estimated at 6.9% and 7.1% declines in household income and expenditure per capita, respectively.

(Arouri, Nguyen, & Youssef, 2015) use commune fixed-effect regressions to estimate the effect of natural disasters on household welfare and poverty in Bangladesh. They find that all the three disaster types considered in the study including storms, floods and droughts have negative effects on household income and expenditure. Access to micro-credit, internal remittances and social allowances can help households strengthen their resilience to natural disasters.

(López-Marrero & Yarnal, 2010) use a case study of two flood-prone communities in Puerto Rico to determine how everyday risks influence people's perceptions of and capacity to adapt to floods. The study reveals that people perceive

floods as one of their risks, but they see them as neither the most important nor most severe risk in their lives. Instead, they find other concerns - health conditions, family well-being, economic factors, and land tenure - more pressing. The results suggest that studies of floods should address these multiple risks, mainstreaming flood management and adaptation into the wider context of people's general wellbeing.

Regarding the impact of floods on human health, there are three systematic review studies on the line of time: (1) Examination of the epidemiological evidence; systematic review (Ahern et al., 2005), in which 212 studies before 2004 were reviewed; (2) This was followed by another systematic review of the relationship between floods and human health (Alderman et al., 2012). 35 published articles over 2004-2011 were chosen. (3) A few year later, a comprehensive review was undertaken (Du et al., 2017). All three systematic reviews concluded that the harmful impacts of floods on population include direct mortality and morbidity from infectious diseases and indirect displacement and widespread damage to crops, infrastructure, and property. Most of the existing epidemiology and economics literature shows that floods will increase the global burden of disease, morbidity, mortality, social and economic disruptions, and will place a continuing stress on health services, especially in low-resource countries. It is in these countries where most major floods occur and where vulnerability is the highest.

Floods are expected to impact households in various ways, ranging from the loss of life, injuries and health effects, to the destruction of assets, and reduced incomes. However, little evidence exists to support the impact of floods on household wellbeing. There has been an overwhelming focus on assessing the physical or tangible impacts of flooding; however, much less is known about the intangible impacts or effects on wellbeing of flooding.

(Hudson, Botzen, Poussin, & Aerts, 2017) study the long term impacts on individual subjective wellbeing (SWB) of flood experiences, individual subjective flood risk perceptions, and household flood preparedness decisions. They collected data from households in flood-prone areas in France. The results reveal that individual experience of flood has a large negative impact on their subjective wellbeing that is incompletely attenuated over time. Moreover, floods also reduce the SWB of individuals who are not directly affected by floods, but they expect their flood risk to increase by seeing a

neighbor being flooded. The decomposition of the monetary impacts of flood experience into tangible losses and intangible effects on SWB shows that intangible effects are about twice as large as the tangible direct monetary flood losses. Investments in flood protection infrastructure may be under funded if the intangible SWB benefits of flood protection are not taken into account.

(Hudson et al., 2018) use survey data from flood-prone households in Hue province in Vietnam to estimate the monetary equivalent of subjective well-being (SWB) losses due to flooding. This monetary estimate is derived from finding the amount of monetary compensation that is needed to offset the wellbeing loss from flooding. They estimate that the initial drop in SWB immediately after a flood event is equivalent to up to 300% of annual income in immediate compensation. This shows that the welfare impact of floods is considerable. While a recovery of SWB occurs over time, they find that even 5 years after a flood, the welfare impact still equals a loss that is the equivalent of 40% to 86% of annual income in long-run compensation. The overall welfare losses are significantly larger for women after this period of time (by about 20 to 29 percentage points), indicating a gender-gap in recovery.

The ultimate impact of a flood on a household depends on the household's vulnerability to its effects. In the literature, the vulnerability is often conceptualized as a function of three components; exposure, sensitivity and adaptive capacity (Adger, W. Neil, 2007).

Vulnerability, broadly defined as the potential for loss, is an essential concept in hazard research, and is central to the development of hazard mitigation strategies at the local, national and international level (Cutter, 1996). There are subtle yet complex differences in regard to where vulnerability is placed in the conceptual 'chain of events' (James Lewis, 1999), or where authors seem to refer to vulnerability as an outcome (Downing et al., 1999): 'the degree of loss resulting from a potentially damaging phenomenon'. While (Neil Adger, 1999) provides a similar definition, 'the exposure of groups or individuals to stress as a result of social and environmental change, where stress refers to unexpected changes and disruption to livelihoods', (Winser et al., 2005) defines vulnerability as 'characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of natural hazards'. In most papers on vulnerability to floods, which focus on the household or individual level, the

most vulnerable groups are low-income peoples, migrants, those without insurance or financial reserves, the elderly, and the infirm (Few, 2003). While some authors show the connection between poverty and vulnerability (Tran et al., 2008), others such as (McElwee et al., 2017) conclude that poverty alone cannot explain flood vulnerability. (Douglas, 2009) in a study of floods in South Asia shows that the most vulnerable groups in terms of food security during floods under climate change are women, children, and the poor. A systematic review (Rufat et al., 2015) finds that demographic characteristics are among the most commonly applied social vulnerability indicators and that women and the elderly are often considered among the most vulnerable.

The adaptive capacity to cope is seen as a key component of flood mitigation at the household level. Following the previous studies of coping mechanisms, people experiencing flood risk may take action through physical means to prevent the spread and penetration of floodwaters and to reduce negative effects of flood through actions such as livelihood diversification, relocation of belongings, and sourcing support from the community. (Morrow, 1999) categorizes coping strategies with economic and material resources, human or personal resources (such as education), family and social resources (such as networks of reciprocity), and political resources (such as power and autonomy). The connections between vulnerability and the ownership of a range of assets is highlighted by authors like (Moser, 1998), who state: "The more assets people have, the less vulnerable they are, and the greater the erosion of people's assets, the greater their insecurity." Moser identifies important assets such as labour, housing, social and economic infrastructure, household relations, and social capital.

Therefore, when we take an examine of household context, in which it can absorb the impacts of the floods without suffering long-term effects, adaptive capacity reduces sensitivity.

The strengths and limitations of different types of flood data

Measuring the impacts of natural disasters is the subject of a large literature, wherein there are currently four principal types of weather data used: ground station data, gridded data, satellite data, and reanalysis data. The most basic type of data is the ground station data, which directly observes temperature, precipitation, humidity, barometric pressure, as well as wind speed and direction. Another traditional method is respondents' subjective self-reports of what they consider as an adverse weather shock and its degree of intensity. Both methods have their own advantages. While ground data

provide a measurement of that exact location's climate, some types of weather data are not available in poor and developing countries, which face more severe constraints to their weather monitoring budget (Burke et al., 2014). Subjective measures have the advantage of being theoretically more precise at the local level than information from spatially aggregated data. However, the subjective measures suffer from both practical and methodological shortcomings (Thomas et al., 2010). They can hardly assess varying severities of weather shocks precisely while also raising issues of endogeneity, especially when incorporated in the vulnerability of the household in question. While global meteorological databases are available, with the exception of the cyclone databases (UNEP/DEWA/GRID-Europe, n.d.) they typically do not have a high resolution.

When comparing different data sources in measuring floods and their impacts, Guiteras, Jina, and Mobarak (2015) compare rainfall data versus flooding data, and self-reports versus satellite images. Their paper makes two key contributions: first, they conclude that objective long-run time series measures of floods will allow us to study human behavioral responses to changes in the distribution of disaster events. Second, they show that rainfall and self-reported exposure are weak proxies for true flood exposure; that measurement error is likely to be correlated with important determinants of socioeconomic outcomes, in particular mean exposure to floods.

To circumvent these weaknesses, we use an external long-run time series measures of floods based on satellite image data. Additionally, as the employed surveys do not refer directly to flood impacts, we avoid endogeneity issues related to the subjective exaggeration of the floods' impacts.

3.2 METHODOLOGY

This research uses a household dataset collected by the "DFG-FOR 756: Vulnerability to Poverty in Southeast Asia" project. This data source is enriched by flood indicators retrieved from daily satellite MODIS Flood Water images (MFW). These satellite images were provided by NASA product version 4.9. The flood areas were constructed using Geographical Information Systems (GIS) and Google Earth to draw neighborhoods of villages. Linking these data sources with a panel dataset of rural households in Thailand and Vietnam allows us to estimate the impact of varying flooding intensities on an array of household welfare outcomes in a panel regression

setup. The following sections will describe our data sources and estimation approach in more detail.

3.2.1 Household data

The panel data consists of 4,400 rural households interviewed in 2007, 2008, 2010 and 2013, in six peripheral provinces of Thailand and Vietnam.[3] These include three provinces in Northeast Thailand, namely Buri Ram, Ubon Ratchathani and Nakhon Phanom, and three provinces from the northern central coast and western highlands in Vietnam, namely Ha Tinh, Thua Thien Hue and Dac Lac (see the map of study area in Appendix Figure B.1). These six provinces were chosen because they offer excellent conditions to undertake such research on vulnerability. Although they have experience with high rates of economic growth and success in poverty reduction, they have also suffered from various types of shocks. Among those, weather shocks are considered as a factor that keeps many households in these areas below the poverty line. A majority of the households in all six provinces are engaging in agriculture activities, informal self-employment, and off-farm employment.

In line with the overall objective of the project "Vulnerability to Poverty in Southeast Asia", the target population were rural households, which are poor or vulnerable to poverty. The sampling procedure applied was a three-stage cluster sampling with explicit strata for agro-ecological zones in Vietnam and implicit stratification in Thailand.[4] As the attrition rate over the four-waves panel lay at a relatively low 5%, we are able to include around 4000 households in the main specification sample. In the main specifications, we work with a total sample of about 4000 households. As a rich dataset, it contains information about demographic composition, health, educational achievements, economic activities, agricultural activities, shocks and risks, employment, financial activities, assets and housing conditions, network and subjective assessment of wellbeing of the sampled households. The survey also includes a section for village heads, which provides fundamental information of the villages. A full list of the relevant variables as well as their definitions may be found in Appendix Table A3.1.

For study how flood shocks impact on household welfare in multi-dimensions, we use all the above-listed information from sections for individuals, household heads, and village heads provided in household surveys. Further, we use available data to create household income compositions, household consumption categories, and measures of subjective assessment of wellbeing of households. In the survey, there are questions asking about household subjective life satisfaction based on the evaluation of

their own wellbeing as a whole, the expectation of minimum net monthly income for their household, and the subjective comparison with other households in their community or in their country. The answers are categorized in an ordinal scale from 1 to 5. We use that variety of questions combined with households' actual income to create a subjective wellbeing variable (SWB), which is a measure of overall household's subjective wellbeing. The outcome is measured in an ordinal scale from 1 to 5, where (1) denotes very dissatisfied (2) dissatisfied (3) neither satisfied nor dissatisfied (4) satisfied, (5) very satisfied. The variable SWB is alternatively measured in both the short term and long term. In the short term, the reference time is from the previous year of the survey year to the next year. In the long term, the reference time is five year ago to the next five years.

As a rich dataset, we have sufficient information for control variables at two levels: household and village. At the household level, we control *Social-demographic* factors such as shares of age groups, gender of household head, marital status of household head, family type, household size, ethnic/ religion identification; the surveys are conducted in rural areas therefore the classification of urban/rural is not necessary in this study. We also control *Material condition* such as household wealth, fluctuation of income, housing quality. Further, we control the *Quality of life* such as employment in household, health status in household, education of household members and household head, social connections. At the village level, we control for village infrastructure, village joint agricultural program,[5] the assess to sanitation and public waste disposal in village, epidemic in the village, and security in living community.

To capture both direct and indirect effects, and illuminate the implicit costs associated with some of the coping strategies, in this study we investigate whether the vulnerability to flooding depends on the economic status of a household by testing through interactions with some coping strategies such as assets (present value), off-farm income (incomes from waged employed activities), insurance mechanism, and social networks. We also examine the role of health insurance in coping with flood-related health expenditure. In addition, households were asked what were the three major shocks that affected their household in the last year, and their coping activities to deal with the shock events. This information indicates if a household in reality took some ex-post action to cope with shock events.

3.2.2 Flood data

The main flood indicator used in this research is a direct measure of the inundated area of the villages in the study areas. We calculate the proportion of a village area that is covered by floodwater over one year.

To calculate the flood indicators, we use the daily satellite MODIS Flood Water images (MFW) provided by NASA, product version 4.9, which produces daily surface and floodwater maps at approximately 250m resolution, in 10x10 degree tiles for South Indochina (see the map in Appendix Figure B.2). This area includes all six provinces in the study. MFW images are used for the period between 2003 and 2013.

To obtain the measure of floods in one year, we join all daily MFW into monthly images, after which all monthly images are unified into yearly products. Each composited yearly image gives an estimate of surface floodwater during the time period, which contains information on the proportion of areas inundated. Figure 3.1 is an example of a flooding map for Hue province from May 2012 to April 2013. To calculate flood indicators at the village level, we needed village administrative maps. However, currently there is no available administrative boundary of villages in rural Vietnam and Thailand. The smallest unit that the Global Administrative data provides is at the sub-district level. Thus, Google Earth was used to draw village boundaries. Drawing was based on the coordinates of one point that belongs to the village,[6] and also referred to the boundary of its commune, and an image of the village which can be viewed on Google Earth (see an example in Appendix Figure B.3). Lastly, we take the inundated area in one year and divide it by the village's area to obtain the proportion of the village area that has been inundated during the year; the value of this indicator lies between 0 and 1. This measure is the main indicator for analysis.

This study follows the definition of flood from the Centre for Research on the Epidemiology of Disasters (CRED). It states that flooding is the "presence of water in areas that are usually dry". Within this definition we choose to regard the most important source of destruction attributable to a flood event as that part of local inundation which is visible in satellite images (see an example in Append Figure B.4). A limitation of using satellite images to discern floodwater is missing data.[7] Cloud cover is a significant challenge, as it is not uncommon for atmospheric conditions to obstruct quality observations for days to weeks during the monsoon season. Though compositing routines are used to limit the effects of clouds, there are no guarantees that cloud cover will break during any MODIS overpass (Ahamed & Bolten, 2017).

In this research, we use 3-day composite product MFW, which is considered best to limit cloud-shadow issues. According to (Nigro et al., 2014) MODIS product is rated as almost perfect (five starts) for flood detecting in South Indochina (see the evaluation rating in Appendix Figure B.5). Two alternative flood indicators were created to check robustness. The first is the 'flooding days' variable that counts the number of days in one year that a village has floodwater. The second variable, 'floodwater variation', is a measure of the deviation of floodwater area in the current year with the average floodwater area during the last five years.
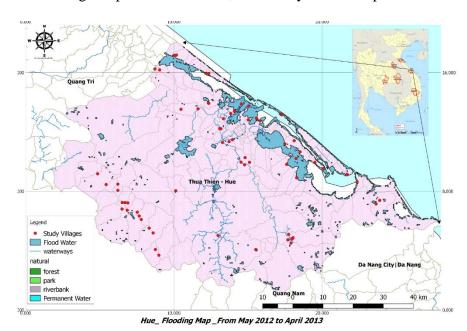
Figure 3.1: Flooding Map of Hue Province, from May 2012 to April 2013

Hue_ Flooding Map _From May 2012 to April 2013

Source: Author's calculation

3.2.3 Descriptive statistics of the sample

Table 3.1 below provides summary statistics of the main variables used in the analysis. The sample is pooled across all four waves. On average, the households in the survey have 4 people in each house. Men function as head of the majority of the households, with only 23% of households being headed by a woman. As the surveys are conducted in poor rural areas, poor households account for 29% of the sample. Overall, approximately 14% of the heads of households have completed their secondary school, in the sample of study individuals who completed secondary education are few, it is possible that low education is a factor making households more vulnerable to poverty. However, we can see a brighter picture when looking at the share of household members who are still studying, which at 28% suggests that the number of household members

pursuing secondary education is rising compared with the existing level of education in the adult generation.

Table 3.1: Household characteristics

	Mean	SD	Min	Max
Household size	4.09	1.75	0	19
Female head (1/0)	0.23	0.42	0	1
Poor household (1/0)	0.29	0.45	0	1
Education of head	0.14	0.34	0	1
Dependency ratio	0.66	0.70	0	6
Share household members are in school	0.28	0.25	0	1
Household produce crops (1/0)	0.88	0.32	0	1
Share household members as non-agricultural employment	0.40	0.30	0	1
Saving in household (1/0)	0.64	0.48	0	1
Household has free Health Card (1/0)	0.80	0.40	0	1
Household member has health insurance (%)	0.09	0.22	0	1
Observations	15976			

Note: Consumption and income variables have been converted to 2005 USD.

Source: Sample of panel household data 2007, 2008, 2010, 2013; author's calculation.

The dependency ratio[8] in the sample is quite high; this phenomenon demonstrates a fact in households in rural southeast Asia that "grandparents in the villages take care of the grandchildren while their own children work outside and often far from the village" (Hardeweg & Waibel, 2009). It is obvious that agriculture plays a major role in rural areas with 88% of households producing crops. However, they often have a second job which is mostly outside agriculture: the average share of household members work as non-agricultural employment is 40%. Although poor people spend most of their income on foods, they do have a habit of saving money for necessary time, there are about 64% of household has at least one saving in house. The percentage of households has a free health card is 80%, while only 9% of the sample are using private health insurance.

Table 3.2: Household income composition

Income Source	Full Sample	Thailand	Vietnam
Total household annual income	7096	7610	6053
Household income from off-farm employment	1804	2147	1252
Household income from self-employment	1659	2010	1064
Remittance receive from household members or relatives	1033	1256	632
Household income from all crops	1432	1336	1468
Household income from livestock	299	228	484
Household income from hunting and aquaculture	420	155	109
Other incomes	499	478	1044
N (households)	*15971*	*7979*	*7992*

Note: Consumption and income variables have been converted to 2005 USD.

Source: Sample of panel household data 2007, 2008, 2010, 2013; author's calculation.

Table 3.2 show mean of income composition in the full sample and for Thailand and Vietnam in particular. On average the annual household income is approximately 7096 USD, Thailand consistently having a higher annual household income than Vietnam except for incomes from crop and livestock. Although agriculture is the major work activity in the rural areas, the incomes from agriculture contribute around 30% to the total income; the remaining 70% of income come from non-agricultural activities, remittances and other sources.

Table 3.3: Household consumption categories

Consumption categories	Full Sample	Thailand	Vietnam
Total annual income per capita	1935	2109	1586
Total consumption per capita	1740	2005	1278
Consumption per capita for foods	871	919	644
Consumption per capita for non-food	442	523	301
Consumption per capita for rice	284	339	195
Consumption per capita for education	111	130	74
Consumption per capita for health care	42	28	59
N (households)	*15962*	*7978*	*7984*

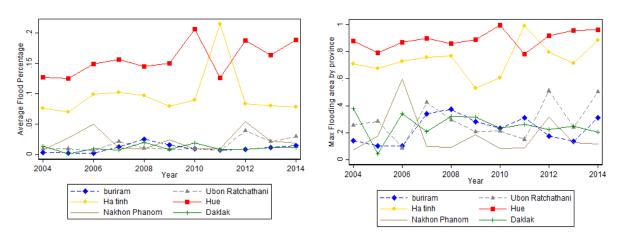Note: Consumption and income variables have been converted to 2005 USD.

Source: Sample of panel household data 2007, 2008, 2010, 2013; author's calculation.

Table 3.3 show mean of annual household consumption per capita. On average of annual total consumption per capita is 1740 USD, this is roughly 90% of their income per capita. The mean per capita in Thailand is consistently higher than in

Vietnam, as a result of higher income. However, families in Thailand spend about 95% of their income, compared to only 81% in Vietnam. It can be seen that the distribution of consumption is mainly for food and rice - about 65% of the total - while the expenditure on education and health are only 6% and 3% respectively. Health expenditure in Thailand is lower than in Vietnam, since access to free health cards in Thailand is very high at 95%, while only 56% of households in the sample of Vietnam have free health cards.

Figure 3.2 : The mean of each village floodwater area per year, by province

Figure 3.3: The maximum of village floodwater area per year, by province

Flood data of 440 villages in 10 years

Source: author's calculations

Figure 3.2 shows the average proportion of each village floods per year by province. The two most affected provinces are Hatinh and Hue in Vietnam, which continuously exhibited larger average flood levels, the two least effected provinces are Buriram in Thailand and Daklak in Vietnam. While Figure 3.3 shows the maximum of village floodwater areas per year by province. The most affected villages in Hue province, Vietnam experience between 80 – 99% of floodwater area. The variation of the maximum floodwater areas fluctuates throughout the year, but the most affected provinces have large floodwater in every year.

3.2.4 Empirical strategy

The effects of floods on household welfare are analysed using a three-part regression setup. First, we examine the direct effects of floods on household incomes and consumptions including health expenditure per capita. Second, we investigate how households are living with floods through analysis their coping strategies. Third, we study

the relationship between floods and household subjective wellbeing. The baseline specifications for each part may be found below:

$$W_{hvt} = \beta_0 + \alpha_1 F_{vt} + \beta_1 H_{hvt} + \delta_p + \rho_t + \varepsilon_{hvt} \qquad (1)$$

Where W_{hvt} denotes the outcomes of household welfare for each household h, living in village v in year t. The outcome W_{hvt} is measured in three different ways, namely: household income compositions, household consumption categories, health expenditure per capita in households. Variables of incomes and consumptions are logged before analysis.[2]

F_{vt} represents a continuous flood indicator, measuring the average of the proportion of a village's area that has been covered by floodwater in the previous and the year of survey, and ranging from 0 to 1. The average flood of two consecutive years is analyzed instead of floods in the current year due to planting and harvesting seasons.

The matrix H_{hvt} captures the socio-demographic characteristics of households including households' wealth, agriculture assets and land usage for agriculture production, also infrastructure index of village when households are living.
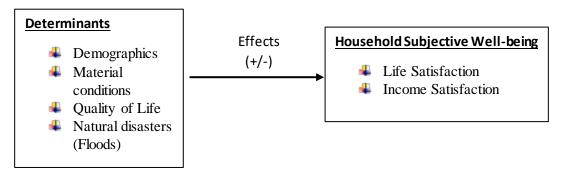
δ_p and ρ_t are full set of province and wave fixed-effects to account for unobserved differences between provinces (p) and surveys years (t). The use of a long-term panel data with province and wave fixed effects provides a feasible way to protect incomes and consumption estimates from time-invariant unobserved heterogeneity across localities. We estimate this effect by assuming that the remaining variation in flood levels across villages between years is independent of the unobserved heterogeneities in welfare outcomes of the households. ε_{hvt} is the error term with standard errors clustered at the village level.[10] The coefficient of interest is α_1, which yields the direct effect of floods on household welfare outcomes caused by switching from having no flood to being covered totally by floodwater ($F_{vt} =1$).

Further, we use the same models (1) and add the interaction term $\alpha_2 F_{vt} * C_{hvt}$, in which C_{hvt} indicates the set of coping mechanisms including: public free health card and private health insurances, intra-house insurance schemes (such as assets, saving, remittance, off-farm income, social network). We also examine the actual ability of households to cope with flood shocks. The coefficients of interest are α_1, α_2, and ($\alpha_1 + \alpha_2$). The estimate of α_1 gives the effect of floods on outcome if households don't use the coping strategy. The estimate of α_2 gives the reduction (or exacerbation) effect of

floods due to applying the coping strategies. The sum of coefficient $\alpha_1 + \alpha_2$) shows the total effect of floods on the outcomes if a household has the coping strategy.

To study the effects of foods on household subjective wellbeing, we follow the OECD guideline in measuring subjective wellbeing.

Figure 3.4 : A simple model of Household Subjective Well- Being (SWB)

The purpose of the simple model of household subjective wellbeing in Figure 3.4 is not to provide a comprehensive framework covering all possible elements of household subjective wellbeing. Rather, we intend to control for all core aspects in measuring SWB, which we are able to create within our dataset.

The Determinants include: *Demographics* (age groups shares, gender of household head, marital status of household head, family type, household size, ethnic/ religion identification), the surveys are conducted in rural areas therefore the classification of urban/rural is not necessary in this study; *Material conditions* (household wealth, fluctuation of income, housing quality); and *Quality of life* (employment in household, health status in household, education of household members and household head, social connections, security in living community). In total, we create 35 elements for controls. (For the detail, see Appendix A3.4)

The household subjective wellbeing (SWB) is an assessment of household subjective life satisfaction based on their evaluation of their household own wellbeing as a whole, and their subjective comparison with other households in their community. In addition, the income satisfaction is created by the ratio of the difference between the expected income with the actual income relative to its actual income. The quintile groups indicate the satisfaction levels.

We use the ordinal logit model:

$$SWB_{hvt} = \beta_0 + \alpha_1 F_{vt} + \beta_1 X_{hvt} + \varepsilon_{hvt} \quad (2)$$

Where SWB_{hvt} denotes the outcomes of household subjective wellbeing for each household h, living in village v in year t. The outcome is measured in ordinal scale from 1 to 5, where (1) denotes for very dissatisfied (2) dissatisfied (3) neither satisfied nor dissatisfied (4) satisfied (5) very satisfied.

The matrix X_{hvt} captures a variety of core aspects in measuring subjective wellbeing, including Demographics, Material conditions, Quality of life.

The logit coefficient α_1 is in log-odds unit, this coefficient only returns whether the flood variable has a negative or positive influence on the outcomes. To interpret the effect of floods on outcomes, we need to estimate marginal effects on probabilities for each category if floodwater changes from 0 to 1.

3.3 FINDINGS

This section of the paper presents the empirical results of our analysis. We use the proportion of floodwater area in villages as the main indicator of flood. First, we categorize household income and consumption into different sources to analyze the effects of floods on various aspects of households' life. Second, we examine various coping strategies in households. Further, we investigate the relationship between floods and household subjective wellbeing. Moreover, we run separate regressions for two alternative indicators of flood as robustness checks. All the results shown use heteroscedasticity robust standard errors clustered at the village level.

3.3.1 The effects of floods on household incomes

Table 3.4 paints a picture of impacts of floods on incomes dependent on natural sources. Hunting and aquaculture income is most affected with approximately 103% decrease if the village is flooded totally (max flood=0.99). Livestock income is reduced by roughly 41.5%. Total crops income declines by around 26.4% (total crops income includes incomes from rice, field crops, garden crops or permanent crops, and forest).

Table 3.4: The effects of flood on incomes directly dependent on natural sources

	(1)	(2)	(3)
	Hunting Income	Livestock Income	Crop Income
Flood	-1.030*	-0.415	-0.264
	(-2.36)	(-0.75)	(-1.25)
Observations	9024	7533	7445
Adjusted R2	0.162	0.142	0.190
Wave –FE	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes
Other controls	Yes	Yes	Yes

OLS regressions: Standard errors, clustered at village level. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$;

Dependent variables: (1) Log of household hunting and aquaculture income, (2) Log of household livestock income, (3) Log of household crop income;

Other controls: Household variables, Land use variables, village variables.

Source: Author's calculations. (The detail result table is provided in Appendix A3.2).

Table 3.5 presents the effects of floods on household incomes, which are not directly dependent on natural resources. Since the household's occupational activities can be assumed to be an important factor in estimating its vulnerability to floods, the

results suggest that households who are highly dependent on agriculture may be more vulnerable to floods than households that have capacity to diversify into non-farm occupations. In the sample of study, there are roughly 88% of households involved in agricultural activities; however, members of households often have a second job outside agriculture, the share of non-agricultural employment in households being on average 40% (cross-refer to Table 3.1). This fact might imply that households take up additional jobs or family members go away seeking jobs as a coping strategy. The results in the column (1-2) reflect those possibilities.

Table 3.5: The effects of floods on incomes not directly dependent on natural sources

	(1)	(2)	(3)	(4)
	Self-Employment	Remittance	Off-farm	Total
Flood	1.284*	1.744***	0.0795	0.110
	(1.99)	(4.88)	(0.23)	(1.20)
Observations	10282	12424	10351	10617
Adjusted R2	0.102	0.101	0.0776	0.280
Wave –FE	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes

OLS regressions: Standard errors, clustered at village level. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$;

Dependent variables: (1) Log of household self-employment income, (2) Log of household remittance income, (3) Log of household off-farm income, (4) Log of household total income;

Other controls: Household variables, village variables;

Source: Author's calculations. (The detail result table is provided in Appendix A3.2).

There are three types of incomes are examined: (1) non-farm self-employment income that households have an own-account worker or run own business with family workers, (2) remittance income that households receive from family members or relatives who living away from home, (3) off-farm income that households receive from waged-employed activities. In a village experiencing 100% of floodwater, households receive more than 128% of their income from self-employment, and 174% from remittances from family members. Column (3) shows a positive relationship between flooding and off-farm income, but the coefficient only 7% and not significant. The findings show that households are seeking jobs to compensate their lost agricultural

incomes by non-agricultural incomes.

Findings reported in this section show a shift of employment from agricultural sector to other sectors of the economy. This shift might be leaded by the opportunities for labor absorption in other sectors in different countries. To clarify this inquiry, we have run separate regressions for Vietnam and Thailand.

Table 3.6: The effects of flood on incomes: Vietnam vs Thailand

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Hunting	Livestock	Crop	Self-employed	Remittance	Off-farm	Total Income
Vietnam							
Flood	-0.743	-0.340	-0.348	1.021	1.970***	0.101	0.144
	(-1.61)	(-0.58)	(-1.64)	(1.51)	(5.38)	(0.30)	(1.59)
Thai Land							
Flood	-0.667	-2.589	-1.199	1.554	-0.488	-1.613	-0.650
	(-0.53)	(-1.27)	(-1.81)	(1.01)	(-0.36)	(-0.74)	(-1.62)
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions: Standard errors, clustered at village level. $^{*}\,p < 0.05$, $^{**}\,p < 0.01$, $^{***}\,p < 0.001$;

Dependent variables: (1) Log of household hunting and aquaculture income, (2) Log of household livestock income, (3) Log of household crop income (4) Log of household self-employment income, (5) Log of household remittance income, (6) Log of household off-farm income;

Other controls: Household variables, village variables.

Source: Author's calculations.

Results in Table 3.6 provide clear evidence that floods reduce incomes dependent on natural sources in both countries. However, the shift of seeking other jobs in Vietnam is mainly toward outside of villages, which is reflected in remittance income (5); while the shift in Thailand has remained inside the villages, which reflects in non-farm self-employed income (4). In total come, households in Thailand are more affected than households in Vietnam. However, this is not a good news for Vietnam, this finding tells a fact that in Vietnam households cope through labor migration to urban areas. This finding matches with the conclusion in one paper published by (Gröger & Zylberberg, 2016), the authors use the same household data for Vietnam to analysis how internal

labor migration facilitates shock coping to a Typoon Ketsana in Vietnam during the 2009 monsoon season. The authors find that "*households with settled migrants ex ante receive more remittances, non-migrant households react by sending new members away who then remit similar amounts than established migrants. This mechanism is most effective with long-distance migration, while local networks fail to provide insurance*". In last decade, there has been waves of people leaving their homeland to seek jobs in cities, this is the major cause for the phenomenon 'transferring the rural poverty to urban poverty' when large amount of illiterate and unskilled migrations moves into urban areas.

3.3.2 The effects of floods on household consumption

The results in Table 3.7 show that overall floods increase all kinds of consumption in households. Health expenditure is the most affected, with a 47% increase in most affected villages (flood=0.99) and a 44.8% increase on education expenditure. These results can be explained by the share of household members still in school being quite high in the sample at around 28% on average. Floods also increase both non-food and food consumption, respectively 21.2% and 11%, but only have a slight effect on rice consumption; this phenomenon is explained by the fact that rice yields in flooded villages are better than in non-affected villages.[11] In total, floods increase household consumption by roughly 18%. These results are equivalent to the average amounts increase in per-capita expenditures for health by roughly 18 USD, education by 50 USD, non-food by 94 USD, food by 96 USD, and the total expenditure increase by 312 USD (cross-refer to Table 3.3).

The results in section 3.3.1 and 3.3.2 show an overview picture of floods on households' income and expenditure in rural Southeast Asia, with negative impacts on both sides. On the one hand, floods reduce agriculture-based incomes and drive away household members to earn money from non-agriculture sources. On the other hand, flood-related impacts increase spending in all aspects of life. This picture suggests to us a hypothesis that "rural households cope with flood shocks by leaving agriculture for seeking extra-income from non-agriculture". In the next section, we will examine this hypothesis.

Table 3.7: The effects of flood on household consumption

	(1)	(2)	(3)	(4)	(5)	(6)
	Health Expenditure	Education Expenditure	Non-food Expenditure	Food Expenditure	Rice Expenditure	Total Expenditure
Flood	0.471*	0.448*	0.212*	0.110	0.029	0.179*
	(2.34)	(2.04)	(2.18)	(1.38)	(0.38)	(2.28)
Observations	7475	7493	7105	7076	7076	7481
Adjusted R2	0.170	0.394	0.373	0.272	0.165	0.390
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions: Standard errors, clustered at village level. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$;

Dependent variables: (1) Log of household health expenditure per cap, (2) Log of household education expenditure per cap (3) Log of household non-food expenditure per cap, (4) Log of household food expenditure per cap, (5) Log of household rice; expenditure per cap, (6) Log of household total expenditure per cap;

Other controls: Household variables, village variables.

Source: Author's calculations. (The detail result table is provided in Appendix A3.3)

3.3.3 Living with floods: coping strategies

From a policy perspective, it will be useful to identify which coping mechanisms are best suited to reduce flood related vulnerability. In this section, we examine how households in rural areas respond to floods through an analysis of their coping strategies. We study both ex-ante and ex-post coping strategies, also both formal and informal coping mechanisms. First, we look at health insurances in coping with cost of flood-related health impacts. Second, we explore several potential intra-channels that households can use as coping strategies to smooth household consumption consequent upon flood shock; in our analysis we use off-farm income, remittances, savings, and help from social networks. Table 3.8 & 3.9 present results for coping strategies, modelled by interacting the floodwater indicator with variables reflecting various coping strategies variables in the household survey. Negative coefficients on the interaction terms would indicate that coping strategies reduces vulnerability to floods.

Coping through public and private health insurance mechanisms

Health insurances used in this analysis are public health card for poor households and private health insurance for individual.[12] Table 3.8 present regression results for using health insurance as coping strategies to health-related impacts. Results in column (2) show that private health insurance can reduce the financial burden for households dealing with the effect of floods by around 26.8%, while a free public health card increases the cost for poor households by around 25.9% (column 1). Since the free health for poor mainly targets household vulnerable to poverty and economic shocks, it is reasonable that households generally display higher risk. Being a part of the program can reduce the cost of health care for poor household around 25.5% in normal situation, however, does not lead to a reduced vulnerability to flood-related health expenditure.

Table 3.8: Public and private health insurance as coping strategies

	(1)	(2)
	Health Expenditure	Health Expenditure
Flood	0.285	0.598*
	(1.05)	(2.41)
Flood* Free Health Card	0.259	
	(0.87)	
Flood* Private Health Insurance		-0.268
		(-0.59)
Free Health Card	-0.255***	
	(-4.17)	
Private Health Insurance		0.229*
		(2.42)
Observations	7473	11060
Adjusted R2	0.172	0.169
Wave –FE	Yes	Yes
Province –FE	Yes	Yes
Other controls	Yes	Yes

OLS regressions: Standard errors, clustered at village level. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$;

Dependent variables: Log of household health expenditure per capita;

Other controls: Household variables, village variables.

Source: Author's calculations.

The results in this section should be understood as indicative, rather than casual effects. In these results, self-selection might play a major role since people are using private insurance more likely because they are suffering from a worse health condition. In developing countries like Vietnam and Thailand, the coverage of the free medical system is much less than ideal. When patients go to hospitals with free public health card, they have to wait so long to get the service, they have to go through many cumbersome procedures and sometimes they also receive cold attention from doctors, therefore in many cases they choose other services for better treatments (Jeffrey Hays, 2012). Therefore, the insignificant coefficients might not justify making direct inferences about free health card program, but possibly reflect the ways it is implemented in the healthcare systems.

Coping through intra-household insurance schemes

In Table 3.9, the interaction terms present the roles of intra-household insurance in coping with the effects of floods on total consumption. Assets, Savings and Remittances indicate significant roles in smoothing household consumptions when dealing with flood shock, while social network tells a story that for households in need of help because they are more vulnerable to flood shock, off-farm income only contributes a small influence.

Column (1) presents evidence that assets-richer household can cope better with floods, while a reduction of around 8.43% in the effects of flood on household expenditure per capita is seen if the household's assets are one quintile higher. Column (2) shows a 20.5% decrease of the effect of flooding on household expenditure per capita if a household has any savings account. Column (3) shows that a household receiving 10% higher remittances can reduce by around 4.6% the impact on household expenditure per capita. Column (4) shows an insignificantly small (2.4%) reduction in household expenditure per capita if the household has 10% higher off-farm income. Column (5) indicates that a household which has a social network option to source help in hardship is more affected by floods, the impact of floods on their total consumption being around 15% higher than a household without a social network option.

Table 3.9: Informal insurance schemes in households as coping strategies

	(1)	(2)	(3)	(4)	(5)
	Total Expenditure	Total Expenditure	Total Expenditure	Total Expenditure	Total Expenditure
Flood	0.422***	0.238**	0.297***	0.258*	0.0880
	(3.43)	(2.81)	(3.46)	(2.58)	(1.02)
Flood* Assets	-0.0843*				
	(-2.46)				
Flood*Saving		-0.205*			
		(-2.03)			
Flood* Remittance			-0.0461***		
			(-3.62)		
Flood*Off-farm				-0.0249	
				(-1.58)	
Flood*Social network					0.151*
					(2.29)
Assets	0.185***				
	(31.37)				
Saving		0.160***			
		(8.27)			
Remittance			0.0267***		
			(12.29)		
Off-farm income				-0.00982***	
				(-3.57)	
Social network					-0.140***
					(-9.01)
Observations	11568	7479	7481	7481	7481
Adjusted R2	0.421	0.396	0.404	0.392	0.398
Wave –FE	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes

OLS regressions: Standard errors, clustered at village level. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$;

Dependent variables: Log of household total expenditure per cap;

Coping strategies: (1) Quintile of household assets, (2) Saving: value 1 if household has a saving, (3) Remittance: Log of household remittance, (4) Off-farm income: Log of household off-farm income, (5) Social network: value 1 if household has any informal social option to ask for when household needs money;

Other controls: Household variables, village variables.

Source: Author's calculations.

In this rural sample, by far, when coping with shocks, a household faces a form of portfolio-choice problem. The portfolio could include everything from economic actions and sales, through borrowing and saving, changing demographics or helps from

relatives. However, these rural households have very limited portfolio-choice, the most frequently reported coping strategies to deal with shocks are 'take up additional occupation' (16%), 'use saving' (13.5%), and 'borrowing or helps from relatives and friends' (14.5%). One of the reasons for this limited choice set is the unavailability of formal supports from public services. There is only 7% reported supports from all Government, Banks, and NGOs. Another reason for the limited choice set is the nature of natural disaster. The floods affect the majority of households in their community simultaneously, and therefore, informal channel such as social networks, do not provide effective method.

The results in this section report a relevant evidence on which coping strategies as used most frequently and effectively in rural areas.

3.3.4 The effects of flood on household's subjective wellbeing

Table 3.10 presents the ordinal logit regressions for assessment of a household's subjective wellbeing (SWB). Household subjective wellbeing variables (SWB1 and SWB3) are measured based on the average score of 'household life satisfaction' and 'subjective comparison wealth to other residents of village and of country'. Level of income satisfaction has been added to created SWB2 and SWB4. Reference time for SWB1 and SWB2 is from the previous year of the survey year to the next year. Reference time for SWB3 and SWB4 is from five year ago to next five years.

Table 3.100: The effects of flood on household subjective wellbeing

	(1) SWB1	(2) SWB2	(3) SWB3	(4) SWB4
Flood	-0.403*	-0.427*	-0.288	-0.319
	(-2.24)	(-2.19)	(-1.68)	(-1.73)
Observations	8118	8118	8118	8118
Categories	5	5	5	5
Pseudo R2	0.0975	0.0873	0.0795	0.0806
chi2	1533.9	1704.0	1371.7	1558.5
Other controls	Yes	Yes	Yes	Yes

Ordinal Logit: Standard errors, clustered at village level. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Dependent variables: Household subjective wellbeing variables

Other controls: Household demographics, household material situations, household's quality of life, social connection and security.

Analysis is following the OECD guideline in measuring subjective wellbeing.

Source: Author's calculations. (The detail result table is provided in Appendix A3.4)

Table 3.11 presents the change in prediction for a household's wellbeing if floodwater area changes from 0 to a maximum of 0.99. The results in column (1) indicate that the probability of 'very dissatisfied' increases around 4.31% when floodwater changes from 0 to 0.99, and all other control variables are held at their constant mean values. Similarly, we can say the probability of 'dissatisfied' increases about 5.56%, the probability of 'neither dissatisfied nor satisfied', 'satisfied' and 'very satisfied' decrease roughly 4.49%, 5.14% and 0.23% respectively. Making a comparison between SWB1 and SWB2, when income satisfaction has been taken into account, the probability of 'very dissatisfied' keep increasing while the probability of 'satisfied' keeps decreasing. Similar interpretations apply to columns (3) and (4).

Table 3.11: The change in predictions for subjective wellbeing level from flood=0 to flood=0.99

SWB Levels	(1) SWB1	(2) SWB2	(3) SWB3	(4) SWB4
Very dissatisfied	0.0431	0.0636	0.0239	0.0608
Dissatisfied	0.0556	0.0414	0.0395	0.0150
Neither dissatisfied nor satisfied	-0.0449	-0.0339	-0.0085	-0.0448
Satisfied	-0.0514	-0.0623	-0.0447	-0.0129
Very satisfied	-0.0023	-0.0087	-0.0102	-0.0181

Source: Author's calculations.

3.4 ROBUSTNESS CHECK

In this section, we use two alternative flood indicators as a robustness check for the validity of the main flood indicator used in our Findings section.

Alternative flood indicators

Table 3.12 shows the relationship between the number of flooding days in a year and household incomes; these regressions are repeated regressions from Table 3.4 & 3.5, with replacement of variable *flooding days* for the variable *flood*. These results tell the same story as those in Table 3.4 & 3.5: flooding days bring negative effects to incomes from crops, livestock, and hunting, and push households away from their farms for seeking incomes from non-agricultural activities. The results in Table 3.12 can be

interpreted as follows: two households have similar conditions living in two different villages. Village A has no flood and village B has 175 flooding days in one year (maximum of the variable *flooding days)*. The household in village B has a lower income from hunting, livestock, and crops; 121%, 101% and 56% respectively. Similarly, in comparison with Table 2b, which demonstrate the relationship between floodwater area with incomes from non-agricultural activities, Table 3.12 presents the same direction of impacts of flooding days on those incomes. If a village has more than 10 flooding days, the incomes from non-agricultural activities changes as follows: off-farm income decreases by 3.1%, self-employment income increases by 8.5%, remittances received from household members or relative increases by 11.7%.

Adjusted-R2 in Table 3.4 & 3.5 are very similar with that in Table3. 12. This shows using floodwater area or flooding days as a flood indicator provides the same coefficient of determination. However, floodwater area is preferred to flooding days because floodwater area can show the intensity of flood, while flooding days only count the days but do not consider the area of floodwater.

Observing flood maps of villages in the study areas over years, we can see that the more affected villages have floodwater more often than the less affected villages. This fact raises an interesting question "whether households suffers much more if there is too much flooding". We try to answer this inquiry by adding the variation of floodwater into analysis. The variation of floodwater is measure by the deviation of floodwater area in current year with the average floodwater area during last five years. Table 3.13 shows both the results of the direct effect of floodwater on outcomes and the effect of flood variations. Overall, floodwater variation has a small effect on hunting income, livestock income, and self-employed incomes. However, variation of floodwater has negative impacts on crops income, off-farm income, and remittance. In extremes case, if floodwater area in the current year is three standard deviations larger than normal floodwater area in the same village, the incomes from crops, off-farm income, and remittance income will reduce by about 15%, 39%, 22% respectively.

Table 3.12: Floods and household incomes

	(1)	(2)	(3)	(4)	(5)	(6)
	Hunting	Livestock	Crop	Off-farm	Self-Employed	Remittance
Flooding days	-0.0069	-0.0058	-0.0032	-0.0031	0.0085*	0.0117***
	(-1.94)	(-1.37)	(-1.68)	(-0.94)	(2.07)	(4.59)
Table 3.13 :						
Flood	-0.968*	-0.320	-0.225	0.220	1.265	1.837***
	(-2.21)	(-0.59)	(-1.05)	(0.64)	(1.94)	(5.10)
Flood	0.0028	0.0272	-0.0513	-0.132	0.0053	-0.0738
variations	(0.03)	(0.26)	(-1.18)	(-1.45)	(0.05)	(-0.81)
Observations	9024	7533	7445	10343	10274	12413
Adjusted R2	0.160	0.143	0.191	0.0808	0.102	0.111
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions: Standard errors, clustered at village level. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$;

Dependent variables: (1) Log of household hunting and aquaculture income, (2) Log of household livestock income, (3) Log of household crop income. (4) Log of household off-farm income, (5) Log of household self-employment income, (6) Log of household remittance income;

Other controls: Household variables, Land use variables, village variables.

Source: Author's calculations.

However, this result should only be used for reference rather than for main finding. One of the limitations of this study is that we only have flood data for ten years from 2003 to 2013 because satellite images of floodwater provided by NASA only from 2002, while our household data is from 2007. In order to create a good indicator of flood's variation, we should have a long-time flood data about twenty years or more.

Overall, we can confidently conclude that two variables, flood and flooding days, provide similar results; however, floodwater area provides a better interpretation. The variation of the floodwater indicator indicates the places in the village where are flooded in the current year, which might not be normally affected during the last five years. As expected, the larger floodwater area in a village compared with the normal level causes negative effects on household incomes; however, as a general conclusion,

the effects of variation of floodwater in villages would cause a small underestimate of the effect of floodwater on household welfare.

Province-year Fixed effects

Much of the empirical literature has so far assumed flood measures to be exogenous. Despite measurement, objective measures may yield biased estimates. First, the repeated occurrence of floods in an area is likely correlated with the possibility of it occurring in the first place, which may in turn affect the level of incomes and expenditures. Second, households in affected areas have likely adapted to these circumstances by coping strategies or building successful livelihood systems called "living with floods". To relieve that worry, we shall compare households from the same province and the same time, who should face a similar flood trend. We perform a robustness check with province-wave fixed effects to account for changes in living conditions over time in each province.

The results in Table 3.14 & 3.15 give us a very similar result compared with the main findings in sections 3.3.1 and 3.3.2. This shows that we can be confident to use the province fixed effects and year fixed effects to control for time-invariant unobserved heterogeneity across locations.

Table 3.14: Flood and household incomes

	(1)	(2)	(3)	(1)	(2)	(3)
	Hunting	Livestock	Crop	Off-farm	Self-Employed	Remittance
Flood	-0.909[*]	-0.292	-0.373	0.00458	1.264	1.851[***]
	(-2.10)	(-0.53)	(-1.72)	(0.01)	(1.94)	(5.25)
Observations	9024	7533	7445	10343	10274	12413
Adjusted R2	0.174	0.146	0.207	0.0829	0.102	0.125
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province*Wave -	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions: Standard errors, clustered at village level. [*] $p < 0.05$, [**] $p < 0.01$, [***] $p < 0.001$.

Dependent variables: (1) Log of household hunting and aquaculture income, (2) Log of household livestock income, (3) Log of household crop income. (4) Log of household off-farm income, (5) Log of household self-employment income, (6) Log of household remittance income;

Other controls: Household variables, Land use variables, village variables.

Source: Author's calculations.

Table 3.15: Flood and household consumptions

	(1)	(2)	(3)	(4)	(5)	(6)
	Health Expenditure	Education Expenditure	Non-food Expenditure	Food Expenditure	Rice Expenditure	Total Expenditure
Flood	0.485*	0.422	0.223*	0.104	0.0346	0.129
	(2.29)	(1.87)	(2.42)	(1.44)	(0.49)	(1.85)
Observations	7475	7493	7105	7076	7076	7481
Adjusted R2	0.174	0.396	0.394	0.332	0.205	0.420
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province*Wave	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions: Standard errors, clustered at village level. $^* p < 0.05,$ $^{**} p < 0.01,$ $^{***} p < 0.001;$

Dependent variables: (1) Log of household health expenditure per cap, (2) Log of household education expenditure per cap (3) Log of household non-food expenditure per cap, (4) Log of household food expenditure per cap, (5) Log of household rice expenditure per cap, (6) Log of household total expenditure per cap;

Other controls: Household variables, village variables.

Source: Author's calculations.

3.5 CONCLUSIONS

This study contributes to the existing literature in two significant ways. First, we construct an external data sets on local flood maps obtained from satellite observations to measure floodwater. This has an advantage of highly precise and objective geographical satellite data. Second, we have completed a previously puzzling picture of the effects of flood on household welfare, in which we look at a multi-dimensional representation of the effects. In general, floodwater reduces household incomes dependent on natural sources, while flooding pushes farmers out of the fields to search for extra income from non-agricultural activities. Moreover, floodwater increases all consumption categories, and creates additional financial cost on health care expenditure. As a results, people living in flooding zone have lower scores of wellbeing. In addition, this research illuminates the efforts that households go to when trying to cope with the impact of flooding. They use both formal and informal coping mechanisms; however, in reality, intra-household coping strategies are commonly used in rural areas and are also effective methods as far as they go. Nevertheless, the results show that the scale of the impact is too large to be coped at household level. We therefore conclude that the experience of living in villages that are subject to flooding is not a happy one.

NOTES

(1) MODIS Flood Water (MFW), MODIS Surface Water (MSW): Currently these are only distributed as vector products (shapefile and kmz) for standard composites. MSW gives all land-based water (with a buffer into oceans) that was observed in the given product. MFW removes from MSW a reference or expected water layer, such that the remaining water is likely to be floodwater.

(2) The OECD work on Measuring Progress and Well-Being (www. oecd.org/measuringprogress) has been addressing these issues in the last few years. These efforts have led to the OECD Better Life Initiative, launched by the OECD Secretary-General on 24 May at the 2011 OECD Forum.

(3) The German Research Foundation (DFG) in Bonn, Germany in 2006 has awarded a special research unit to the Universities of Hannover, Göttingen, and Frankfurt. The subject of the project is the analysis of the role of shocks and risks for the development of poor countries and emerging market economies.

(4) Secondary data for sampling on Thailand was available down to the village level; population density and agro-ecological conditions were assumed to be sufficiently homogeneous; sample design for Thailand is kept simple and aimed at obtaining a self-weighting sample. The provinces in Vietnam were purposively selected for the survey and are geographically more diverse than those in Thailand. While Dak Lak province is part of the landlocked Central Highland, Thua Thien-Hue, and Ha Tinh provinces extend from the coast to the mountainous border to Laos. In order to take into account this heterogeneity, strata for the first stages were defined as agro-ecological zones within the three provinces.

(5) To strengthen the competitiveness of farmers, some agriculture programs are offered. For example, Thailand has the OTOP program and Vietnam has the 135 and 147 program. The objective of the One Tambon One Product (OTOP) project in Thailand is to support local manufactured products and empower people living in communities to use their skills in manufacturing to improve the quality and marketing of local products. Government agencies and the private sector provide support to the villages to create marketable designs and packages. The Program 135 (P135) was established in 1998, in order to implement government policies targeting the most vulnerable communities to promote production and access to basic infrastructure, improve education, train local officials, and to raise people's awareness for better living standards and quality of life.

(6) For each village, one coordinate was recorded by the interviewers during the village interviews. The coordinates were recorded in decimal degrees (latitude, longitude). For example, the geographical coordinates of the village Yang, sub-district Kham Duan, distric Krasang, province Buriam, Thai land is (15.0773638888889, 103.401458333333).

(7) Another limitation of using satellite images is that satellite images of floodwater can only capture the surface of water, but cannot measure the depth of water.

(8) The dependency ratio is a measure showing the ratio of the number of dependents aged zero to 14 and over the age of 65 to the total population aged 15 to 64. This indicator gives insight into the amount of people of nonworking age compared to the number of those of working age. The ratio can be calculated as:

Dependency Ratio = (Number of dependents / Population aged 15 to 64) x 100%.

(9) Working with agriculture incomes we often see negative values, which happens when production costs are higher than revenue; the household data set used in this study is no exception. In the household data, negative values comprise about 15% of observations of crops income, 22.5% of observations of livestock income, 4% of observations of hunting income, and 11% of observations of rice income. We understand that studying weather impacts can sometimes tell meaningful stories about negative incomes, we want to know if we miss any those stories, therefore we compare the results of different methods of transformation; log transformation and inverse hyperbolic sine transformation. And the results from two regressions are very similar, we prefer to using log transformation because of its straight interpretation.

(10) The standard errors are clustered at village level due to sampling design. The survey used a three-stage clustered sampling approach. Provinces were targeted, sub-districts were selected with probability proportional to population size (PPS), followed by a simple random PPS sample of two villages from each sampled sub-district. Lastly, households were randomly sampled with implicit stratification by household size. We account for the survey design using sample weights.

(11) Using the same data sets, in our paper: Le Thi Ngoc Tu, Sebastian Vollmer, Felix Stips (2018). "The effects of floods on agricultural production: a mixed blessing", we find that the effects of floods on agricultural production is mixed. While floods increase expenditures and reduce incomes, they can also increase rice productivity.

(12) In Thailand, since 1975, the Government had made health services available to the poor free of charge. However, the Universal Coverage Scheme(USC) has flowed a long string of efforts to improve equity in health. By 2001, the UCS was covering 48 million members and their families, leaving less than 2 percent of the Thai population without health insurance coverage (Wagstaff & Manachotphong, 2012).

In Vietnam, to improve health care access for low income households, the Vietnamese Government offers the program Health Card for the Poor (HCFP) in 2003. This card was designed to support poor households and ethnic minorities. The program covers inpatient and outpatient health care costs at public providers (Somanathan et al., 2014).

Appendix A3

Table A 3.1: Variable definitions

Variable	Definition
Access to fixed line telephone	Percentage of households in village with access to fixed line telephone
Access to electricity	Percentage of households in village with access to electricity
Access to internet	Percentage of households in village with access to internet
Access to public waste disposal	Percentage of households in village with access to public waste disposal
Access to public water	Percentage of households in village with access to public water
Access to sanitation	Percentage of households in village with access to sanitation
Agriculture assets	Household total present value of agriculture asset items
Agriculture land (1/0)	Dummy variable, takes the value 1 if land is mainly used for agricultural purposes
Agriculture land area	Household total agriculture land area (ha)
Agriculture Village (1/0)	Dummy variable, takes the value 1 if the main employment in the village is agriculture
Area Planted	Household total crop area planted (ha), or households total rice area planted (ha)
Cooking fuel (1/0)	Dummy variable, takes the value 1 if household uses gas or electric for cooking
Cope (1/0)	Dummy variable, takes the value 1 if household took any ex-post coping activities to deal with flood event
Crop Land (1/0)	Dummy variable, takes the value 1 if land is mainly used to grow crops
Dependency ratio	Number of dependents / number of aged 15 to 64
Epidemic in village (1/0)	Dummy variable, takes the value 1 if village has epidemic problem
Female head (1/0)	Dummy variable, takes the value 1 for households that are headed by a woman
Firm density in village	Number of firms in village per 100 inhabitant
Flooding days	The number of days in one year that a village has floodwater
Floodwater area	Average of the proportion of a village area that has been covered by floodwater in the previous year and current year
Floodwater variation	standard deviation of this year floodwater area from the average of last 5 year floodwater area
Free health card (1/0)	Household has free health card
Head education	Categorical variable, which takes values 0-6

	0: No education
	1: Primary not completed
	2: Primary completed
	3: Lower secondary completed
	4: High school/ vocational completed
	5: Some college / advanced vocational completed
	6: University or higher
Health insurance	Member has private health insurance
Household Assets	Household total present value of asset items
Household crop expenditures	Household total expenditure for all crop production, includes expenditures for machinery, hired labor, seeds and seeding, fertilizer materials, pesticides materials, and irrigation
Household crop income	Household annual income from crop production
Household hunting income	Household total income from fishing, hunting, collecting, or logging activities
Household income	Household total annual income
Household income per capita	Household total annual income per capita
Household livestock income	Household annual income from livestock
Household produce crops	Households that grow rice, field crops, permanent crops, or forest in the year of study
Household size	Household nucleus size, includes only members of the family who stay in the household for more than 6 months
Income fluctuation (1/0)	Dummy variable, takes the value 1 if household has income fluctuation in last 12 months
Land in Village (1/0)	Dummy variable, takes the value 1 if planted parcel land in the same village
Land Tenure (1/0)	Dummy variable, takes the value 1 of household owned land
Majority (1/0)	Household is majority group (Kinh in Vietnam, Thai in Thailand)
Married (1/0)	Household head is living with married partner
Mechanic Irrigation (1/0)	Dummy variable, takes the value 1 if the farmer uses mechanic irrigation to grow crops (pipe, tap, pumped from public irrigation canal)
Non-farm employee (1/0)	Household has non-farm employee
Own house (1/0)	Household owns the house
Persons per room	Household size / number of rooms
Poor household (1/0)	Dummy variable, takes the value 1 for poor families that have an income per capita below the poverty line (1.9 USD per day)

Private toilet (1/0)	Household has a private toilet
Rain Irrigation (1/0)	Dummy variable, takes the value 1 if farmer depends on rain for irrigation to grow crops
Religion (1/0)	Household has a religion
Rice Village (1/0)	Dummy variable, takes the value 1 if main agriculture activity in village is rice production
Saving (1/0)	Dummy variable, takes the value 1 if household has any saving account
Share children	Proportion of children in household = (number of aged from 0 to 15 / household size)
Share elder	Proportion of elder in household = (number of aged from 60 / household size)
Share good health	Proportion of members of household with a good health status
Share health insurance	Proportion of members in household using private health insurance
Share in school	Proportion of members in household still in school
Share infant	Proportion of infant in household = (number of aged from 0 to 5 / household size)
Share male	Proportion of adult male in household
Social problem in village (1/0)	Dummy variable, takes the value 1 if village has any social problem
Solid house (1/0)	Household is living in solid house (house is constructed by wooden or cement)
Time to town	Travel time from village to the district town in minutes
Use Fertilizer (1/0)	Dummy variable, takes the value 1 if the farmer spends money on fertilizer to grow crops (or rice)
Use Pesticides (1/0)	Dummy variable, takes the value 1 if the farmer spends money on pesticides to grow crops (or rice)
Village infrastructure	Village infrastructure index in quintiles
Village join agriculture program (1/0)	Dummy variable, takes the value 1 if the village participates in one of the agricultural programs (OTOP in Thailand, program 135 or 147 in Vietnam)
Wage employee (1/0)	Household has wage employee

Notes: Expenditure and income variables have been converted to 2005 USD

Source: Author's calculation

Table A 3.2: The effects of floods on household incomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Hunting	Livestock	Crop	Off-farm	Self-Employment	Remittance	Total
Flood	-1.030*	-0.415	-0.264	0.0795	1.284*	1.744***	0.110
	(-2.36)	(-0.75)	(-1.25)	(0.23)	(1.99)	(4.88)	(1.20)
Assets	-0.134***	0.134***	0.162***	-0.0259	0.615***	0.166***	0.252***
	(-8.85)	(5.94)	(13.14)	(-0.69)	(18.59)	(6.40)	(27.43)
Household size	0.142***	0.157***	0.0760***	0.491***	0.128***	-0.281***	0.120***
	(7.62)	(6.07)	(6.34)	(16.59)	(4.83)	(-13.44)	(18.56)
Head Education	-0.161***	0.0362	0.0356	0.414***	0.253***	-0.211***	0.107***
	(-5.34)	(0.81)	(1.68)	(7.89)	(5.46)	(-5.74)	(10.08)
Share working age	0.0739	0.178**	0.0819*				
	(1.44)	(2.76)	(2.40)				
Crop Land (1/0)	0.253***	0.307**	0.322***				0.0341
	(3.48)	(3.11)	(5.99)				(1.44)
Agriculture Village	0.431	0.685	0.409	-1.376***	-0.645	-0.482*	
	(1.11)	(1.50)	(1.70)	(-4.12)	(-1.92)	(-2.33)	
Village join Agriculture Program	0.0343	0.163	0.0384	-0.118	-0.0673		
	(0.39)	(1.58)	(0.78)	(-1.06)	(-0.66)		
Village's infrastructure index	-0.131**	-0.0553	-0.0296	0.0353	0.0344		
	(-3.27)	(-1.22)	(-1.40)	(0.75)	(0.80)		
Area Planted			0.00225**				
			(2.67)				
Land Tenure			0.229***				

108

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			(3.43)				
Mechanic Irrigation			0.149*				
			(2.51)				
Rain Irrigation			0.00474				
			(0.09)				
Land in Village			-0.117				
			(-1.41)				
Use Pesticides			0.370***				
			(7.09)				
Use Fertilizer			0.617***				
			(4.03)				
Share non Agriculture Employment						0.336***	
						(11.27)	
Total Land						0.171***	
						(5.42)	
Poor in previous wave						-0.310***	
						(-13.78)	
_cons	3.861***	1.476**	4.165***	2.546***	-3.246***	4.496***	5.717***
	(9.28)	(2.86)	(12.73)	(5.45)	(-7.01)	(15.19)	(79.02)
Observations	9024	7533	7445	10351	10282	12424	10617
Adjusted R2	0.162	0.142	0.190	0.0776	0.102	0.101	0.280
Wave –FE	yes	yes	yes	yes	yes	yes	yes
Province –FE	yes	yes	yes	yes	yes	yes	yes

OLS regressions. Standard errors, clustered at village level. $^*\,p < 0.05$, $^{**}\,p < 0.01$, $^{***}\,p < 0.001$

Dependent variables: (1) Log of household crop income, (2) Log of household livestock income, (3) Log of household hunting and aquaculture income, (4) Log of household off-farm income , (5) Log of household self-employment income, (6) Log of household remittance income, (7) Log of household total income;

Source: Author's calculations

Table A 3.3: The effects of flood on household consumption

	(1) Health	(2) Education	(3) Non-food	(4) Food	(5) Rice	(6) Total
Flood	0.471*	0.448*	0.212*	0.110	0.0292	0.179*
	(2.34)	(2.04)	(2.18)	(1.38)	(0.38)	(2.28)
Share infant in house	0.0541					
	(0.36)					
Share elder in house	0.761***					
	(9.22)					
Head Education	0.0129	0.115***	0.0899***	0.0410***	0.00357	0.0869***
	(0.60)	(3.95)	(8.87)	(5.54)	(0.40)	(10.78)
Assets value, lagged	0.106***	0.175***	0.196***	0.0754***	0.0432***	0.164***
	(6.50)	(10.72)	(26.89)	(11.81)	(5.89)	(26.88)
Private Toilet	0.172**			0.0555**	-0.0234	
	(2.81)			(2.60)	(-1.00)	
Cooking Fuel	0.261***			0.156***	-0.0684**	
	(5.11)			(7.97)	(-3.00)	
Access to Sanitation	0.00161**			-0.000129	-0.00144***	-0.000130
	(2.70)			(-0.35)	(-4.03)	(-0.42)
Access to waste disposal	-0.00112			-0.000956**	-0.00184***	-0.000390
	(-1.40)			(-2.61)	(-3.37)	(-1.23)
Time to town	0.000547	-0.000314	-0.00119	0.000498	0.000798	-0.000500
	(0.35)	(-0.19)	(-1.94)	(1.01)	(1.54)	(-0.91)
Village Infrastructure Index	0.0195	0.0608**	0.0202			
	(0.91)	(2.75)	(1.83)			
Epidemic in Village	-0.0585					
	(-0.74)					

	(1)	(2)	(3)	(4)	(5)	(6)
Share in school	4.772***					
	(17.05)					
Access to electricity	0.00419**	0.000963				0.00140
	(3.13)	(1.08)				(1.87)
Access to Public water	-0.000677	-0.0000404				0.000230
	(-0.83)	(-0.11)				(0.81)
Access to Line telephone	-0.00149*	-0.000661*				-0.00129***
	(-2.48)	(-2.32)				(-5.42)
Access to Internet	0.00666	0.00733*				0.00492**
	(1.14)	(2.57)				(2.69)
Dependency ratio			-0.188***	-0.163***	-0.144***	-0.187***
			(-13.88)	(-15.52)	(-10.97)	(-17.56)
Agriculture village				-0.0735	0.0750	-0.0597
				(-1.15)	(0.96)	(-0.93)
Village join Program				-0.0408	-0.00342	
				(-1.94)	(-0.13)	
_cons	0.164	-0.174	4.198***	6.028***	5.316***	6.112***
	(0.95)	(-0.85)	(37.11)	(65.29)	(48.25)	(55.31)
Observations	7475	7493	7105	7076	7076	7481
Adjusted R2	0.170	0.394	0.373	0.272	0.165	0.390
Wave –FE	Yes	Yes	Yes	Yes	Yes	Yes
Province –FE	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Standard errors, clustered at village level. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Dependent variables: (1) Log of household health expenditure per cap, (2) Log of household education expenditure per cap (3) Log of household non-food expenditure per cap, (4) Log of household food expenditure per cap, (5) Log of household rice expenditure per cap, (6) Log of household total expenditure per cap.

Other controls: Household variables, village variables. *Source:* Author's calculations

Table A 3.4: The effects of flood on household subjective wellbeing

	(1) SWB1	(2) SWB2	(3) SWB3	(4) SWB4
Flood	-0.403*	-0.427*	-0.288	-0.319
	(-2.24)	(-2.19)	(-1.68)	(-1.73)
Household size	0.0619**	0.0872***	0.0552**	0.0775***
	(3.22)	(4.91)	(2.92)	(4.38)
Share age 0_4	-0.484*	-0.561**	-0.368*	-0.503*
	(-2.57)	(-2.91)	(-2.04)	(-2.40)
Share age 15_18	-0.526***	-0.748***	-0.544***	-0.713***
	(-3.40)	(-5.09)	(-3.71)	(-4.70)
Share age 19_30	-0.0953	-0.169*	-0.0375	-0.0863
	(-1.27)	(-2.24)	(-0.52)	(-1.15)
Share age 31_40	0.0313	-0.0362	0.0410	-0.0241
	(0.28)	(-0.34)	(0.39)	(-0.22)
Share age 41_50	-0.241	-0.162	-0.284*	-0.299**
	(-1.96)	(-1.40)	(-2.36)	(-2.58)
Share age 51_60	-0.407**	-0.201	-0.632***	-0.439***
	(-3.23)	(-1.73)	(-5.18)	(-3.61)
Share age 5_14	-0.540***	-0.792***	-0.543***	-0.754***
	(-3.96)	(-5.70)	(-4.17)	(-5.45)
Share age 61_64	-0.431*	-0.125	-0.868***	-0.507**
	(-2.25)	(-0.66)	(-4.66)	(-2.72)
Share age 65_120	-0.665***	-0.228*	-0.989***	-0.665***
	(-5.62)	(-1.96)	(-8.64)	(-5.59)
Female head	-0.0319	-0.0631	0.00456	-0.0421
	(-0.41)	(-0.80)	(0.06)	(-0.52)
Household head married	0.204*	0.0555	0.137	0.0912
	(2.50)	(0.72)	(1.70)	(1.14)
Head education	0.118***	0.118***	0.144***	0.135***
	(4.70)	(4.78)	(5.38)	(5.36)
Share male	-0.141	0.0505	-0.0927	-0.00350
	(-1.18)	(0.45)	(-0.77)	(-0.03)
Majority	0.0542	0.129	-0.0712	0.0242
	(0.64)	(1.64)	(-0.84)	(0.30)
Has Religion	0.280***	0.00180	0.104	-0.0175
	(3.68)	(0.03)	(1.44)	(-0.24)

Assets value, lagged	0.320***	0.337***	0.258***	0.289***
	(16.64)	(17.73)	(13.88)	(15.56)
Income Fluctuation	-0.698***	-0.660***	-0.749***	-0.710***
	(-18.43)	(-17.30)	(-18.94)	(-18.61)
Cooking Fuel	0.479***	0.364***	0.388***	0.374***
	(8.15)	(6.25)	(6.53)	(6.41)
Private Toilet	0.282***	0.195**	0.211***	0.174**
	(4.43)	(2.93)	(3.32)	(2.72)
Own house	0.370	0.557*	0.366	0.489
	(1.47)	(2.32)	(1.58)	(1.87)
Persons per Room	-0.0969***	-0.109***	-0.0742***	-0.0839***
	(-4.73)	(-5.04)	(-3.50)	(-3.90)
Solid house	0.169**	0.126*	0.0986	0.102
	(3.16)	(2.38)	(1.77)	(1.88)
Non-Farm Employment In house	0.200***	0.325***	0.163**	0.285***
	(3.77)	(6.53)	(3.08)	(5.52)
Waged employment In house	-0.0615	0.0885	-0.0533	0.0430
	(-1.11)	(1.55)	(-1.00)	(0.78)
Share health Insurance	0.107	0.333***	0.226*	0.370***
	(1.05)	(3.37)	(2.26)	(3.59)
Share Good health In house	0.382***	0.304***	0.454***	0.392***
	(7.21)	(5.66)	(8.51)	(7.20)
Social problem In village	0.161**	0.0905	0.187**	0.131*
	(2.64)	(1.58)	(3.02)	(2.21)
Epidemic in Village	-0.0711	-0.0227	-0.145	-0.113
	(-0.78)	(-0.26)	(-1.73)	(-1.38)
Access to Electricity	-0.00214	-0.00266	-0.00372**	-0.00537**
	(-1.15)	(-1.16)	(-2.58)	(-2.74)
Access to Public water	0.00217**	0.00200**	0.00137	0.00126
	(2.84)	(2.65)	(1.87)	(1.67)
Access to Sanitation	0.000407	0.00163*	0.000268	0.00119
	(0.54)	(2.28)	(0.35)	(1.64)
Access to Waste disposal	-0.000308	-0.000294	-0.000235	-0.000347
	(-0.36)	(-0.35)	(-0.24)	(-0.39)
Access to Line telephone	-0.00146*	-0.00284***	-0.00197**	-0.00251***
	(-2.06)	(-3.98)	(-2.72)	(-3.61)

Access to Internet	-0.00348 (-0.92)	-0.00359 (-1.15)	-0.00289 (-0.79)	-0.00531 (-1.81)
cut1				
_cons	0.319 (0.92)	0.982** (2.62)	-1.006** (-3.13)	0.548 (1.47)
cut2				
_cons	2.104*** (5.99)	2.341*** (6.27)	0.592 (1.84)	2.000*** (5.36)
cut3				
_cons	3.943*** (11.18)	3.777*** (10.14)	2.326*** (7.25)	3.686*** (9.92)
cut4				
_cons	7.431*** (20.48)	6.317*** (16.62)	4.536*** (14.00)	4.329*** (11.61)
Observations	8118	8118	8118	8118
Categories	5	5	5	5
Pseudo R2	0.0975	0.0873	0.0795	0.0806
chi2	1533.9	1704.0	1371.7	1558.5

Ordinal Logit. Standard errors, clustered at village level. $^{*}\,p < 0.05,\ ^{**}\,p < 0.01,\ ^{***}\,p < 0.001$

Dependent variables: Household subjective wellbeing variables are measured based on the average score of (household life satisfaction) and (subjective comparison wealth to other residents of village and of country) and (income satisfaction). Reference time for SWB1 and SWB2 is from the previous year of the survey year to the next year. Reference time for SWB3 and SWB4 is from five year ago to next five years.

Other controls: Household demographics, household income situations, household employment status, housing conditions, health status in household, social connection and security.

Analysis is following the OECD guideline in measuring subjective wellbeing
Source: Author's calculations

Appendix B

Figure B 1. Study areas of the "Vulnerability to poverty in Southeast Asia" survey

Source: ("Vulnerability in Southeast Asia - Overview," n.d.)

Figure B 2: MODIS Flood Map 23-23 October 2010, Tilte: 100E020N

Source: ("MFM_2010298_100E020N_3D3OT.Png (PNG Image, 3300 × 2550 Pixels) - Scaled (35%)")

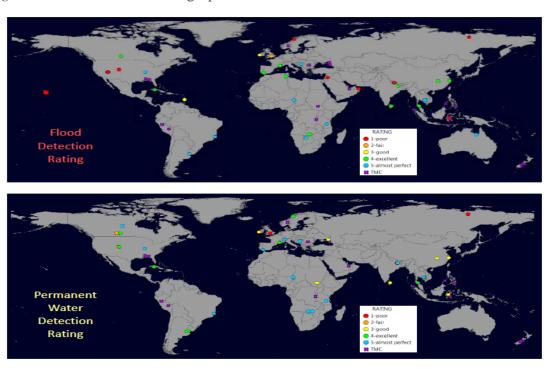*Figure B 3:* Coordinates on Google Earth of study village in Hue Province – Vietnam

Source: Author's work on Google Earth

Figure B 4: Flooding in Ayutthaya and Pathum Thani Provinces in October 2011(right), compared to before the flooding in July 2011(left)

Source: ("File:2011 flooding in Ayutthaya Province-EO-1 merged.jpg - Wikipedia," n.d.)

Figure B 5: MODIS Flood Image product Evaluation

Source: (Policelli et al., 2016)

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