AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2014WR015982

Key Points:
- Household flood losses are estimated using in-person interviews in Bangkok
- In three heavily affects districts of median household, economic costs were US$3089
- Most houses suffered only minor structural damage

Correspondence to:
D. Whittington,
Dale_Whittington@unc.edu

Citation:
Nabangchang, O., M. Allaire, P. Leangcharoen, R. Jarungrattanapong, and D. Whittington (2015), Economic costs incurred by households in the 2011 Greater Bangkok flood, *Water Resour. Res.*, *51*, 58–77, doi:10.1002/2014WR015982.

Received 24 JUN 2014
Accepted 16 NOV 2014
Accepted article online 24 NOV 2014
Published online 8 JAN 2015

Economic costs incurred by households in the 2011 Greater Bangkok flood

Orapan Nabangchang[1], Maura Allaire[2], Prinyarat Leangcharoen[1], Rawadee Jarungrattanapong[1], and Dale Whittington[2,3]

[1]Economy and Environment Program for Southeast Asia, Nonthaburi, Thailand, [2]Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA, [3]Manchester Business School, University of Manchester, Manchester, UK

Abstract This paper presents the first comprehensive estimates of the economic costs experienced by households in the 2011 Greater Bangkok flood. More generally, it contributes to the literature by presenting the first estimates of flood costs based on primary data collected from respondents of flooded homes using in-person interviews. Two rounds of interviews were conducted with 469 households in three of the most heavily affected districts of greater Bangkok. The estimates of economic costs include preventative costs, ex post losses, compensation received, and any new income generated during the flood. Median household economic costs were US$3089, equivalent to about half of annual household expenditures (mean costs were US$5261). Perhaps surprisingly given the depth and duration of the flood, most houses incurred little structural damage (although furniture, appliances, and cars were damaged). Median economic costs to poor and nonpoor households were similar as a percentage of annual household expenditures (53% and 48%, respectively). Compensation payments received from government did little to reduce the total economic losses of the vast majority of households. Two flood-related deaths were reported in our sample—both in low-income neighborhoods. Overall, ex post damage was the largest component of flood costs (66% of total). These findings are new, important inputs for the evaluation of flood control mitigation and preventive measures that are now under consideration by the Government of Thailand. The paper also illustrates how detailed microeconomic data on household costs can be collected and summarized for policy purposes.

1. Introduction

Climate change is increasing the risks populations face from hydrological uncertainty. Water resource planners are devoting more and more attention to the development of planning protocols and procedures that can better incorporate these new uncertainties surrounding the magnitude and consequences of extreme hydrological events such as floods. A common element in all methods for addressing the implications of climate change for water resources planning is the need for better estimates of the economic costs that hydrological risks impose on households and businesses. Decision makers need accurate estimates of these economic costs in order to design and choose improved, cost-effective risk management and adaptation strategies.

Surprisingly, the methodology for estimating the economic costs to households from flood events has not advanced much over the last several decades. Although there have been major theoretical and methodological advances in nonmarket valuation techniques in the environmental and resource economics field, these have not made their way to research on the economic costs to households of major flood events. There are several reasons for this peculiar state of affairs.

First, by definition the precise timing of flood events are unknown in advance and researchers must act quickly after a flood to try to measure the consequences to households while they are fresh in people's minds. Funding for most research is not sufficiently flexible to respond in a timely manner to study the economic costs of unpredictable flood events. Second, dealing with the humanitarian crisis created by major flood events naturally takes precedence over longer-term research objectives. Simply put, researchers have an ethical obligation not to get in the way of relief efforts.

Third, research on flood damages usually has been conducted by teams of engineers, planners, financial analysts, and infrastructure economists, and is largely focused on estimating the financial losses to buildings and contents, for both households and businesses. This is perhaps understandable when the purpose of the study is to determine financial compensation to be paid by government and insurance companies. But the resulting cost estimates will be incomplete measures of the welfare costs imposed by the risk of floods that are needed for improved decision making.

There are no published studies of costs households incur from floods in either industrialized countries or developing countries in which the researchers' findings are based on data collected from affected households using in-person interviews and modern nonmarket valuation techniques. Because the microeconomic literature on estimating the economic costs to households is thin, and because much of the existing research has been conducted by noneconomists, the terminology used in the literature to describe and categorize different types of household costs due to floods is inconsistent and confusing. This study addresses these gaps in the literature on the economic costs households incur from extreme hydrological events such as floods.

In-person interviews were conducted with households in greater Bangkok affected by the 2011 Thailand flood. The 2011 flood in Thailand is an especially interesting case study because it offers a window on the flood management challenges facing millions of people around the world and for their governments in a time of climate change. There are seven megacities in South and Southeast Asia with over 10 million people located near the coast that are experiencing rapid population growth and must confront the combined threats of land subsistence, increased extreme rainfall and storm events, and rising sea levels (Mumbai, Dhaka, Kolkata, Karachi, Manila, Jakarta, and Bangkok).

In this case study, we examine the magnitude and composition of the economic losses experienced by 469 households from the 2011 flood in three of the most affected neighborhoods of the Greater Bangkok Metropolitan area. We first interviewed individuals in these households in January and February 2012, while their memories of the flood were fresh. A second round of interviews was conducted a year later to measure additional recovery costs incurred between January 2012 and January 2013. The attrition rate between the first and second round surveys was 20%; 589 households participated in the first survey. In the first round survey, respondents were asked about the actions they took before the flood arrived to try to reduce the direct and indirect costs incurred as a result of the flood, and the financial expenses they expected in order to repair and replace their property after the flood waters receded. Questions to estimate both health-related and nonhealth-related costs were included in the survey instrument. In the second round survey, we were able to collect data on the actual expenses incurred to repair and replace property damaged in the flood, as well as time lost from work.

The paper is organized as follows. The next, section 2 of the paper provides background on the 2011 Thailand flood. Section 3 describes the study sites and fieldwork protocol. Section 4 describes how the different components of households' economic costs were estimated and the modeling strategy used to examine the factors associated with these costs. Section 5 presents the results, and section 6 offers some concluding observations.

2. Background—The 2011 Thailand Flood

The Chao Phraya River Basin drains about 30% of the surface area of Thailand. Four main rivers—Ping, Wang, Yom, and Nan—merge in Nakhon Sawan province (in Thailand's Upper Central Region) to form the Chao Phraya River. The river begins in the northern, mountainous region of Thailand, and then flows south through the flat central plains. Greater Bangkok is located at the southern, downstream end of the Chao Phraya River Basin in the Chao Phraya river delta near the coast.

In late 2011, Thailand was hit with the worst floods experienced in 50 years (since the floods in1942). The 2011 flood, which eventually inundated much of greater Bangkok, had three distinct phases. The first phase was from March to April when heavy rainfall caused widespread flooding in southern Thailand, resulted in 61 deaths, damaged 600,000 homes, and caused extensive damage to businesses and transportation infrastructure. Rainfall in March 2011 was over 3 times the average for the past 30 years. Land became saturated and further infiltration was limited even before the summer monsoon rains arrived. Eight provinces in Thailand were declared disaster zones.

The second phase was from June to the middle of October when the remnants of five tropical storms hit Thailand. Rainfall in June was 128% of the average. In July and August, rainfall was 150% of the average.

During August and September, monsoon rains were heavier and lasted longer than usual perhaps due to the presence of La Niña. Rainfall in September was 135% of the average and in October 116% of average [*AON*, 2012]. Rainfall in 2011 was considerably greater than rainfall that preceded the last major flood to reach Bangkok in 1995. Total rain in northern Thailand for July to September was 1156 mm, the highest amount recorded since records began in 1901. *World Bank* [2012] estimated the annual probability of such high rainfall to be 1 in 250 years.

Month after month of heavy rains led to widespread flooding in the northern, northeastern, and central portions of Thailand. Major dams filled to capacity and 10 major flood control structures experienced breaches from mid-September to early October. Flash flooding and landslides occurred in central and northern Thailand. This long period of heavy rainfall also caused very high flows in the northern sections of the Chao Phraya River, and these floodwaters spread southward. By mid-September, many provinces in the central part of the basin were affected by the flood. The agricultural lands in the central plain initially served as water retention areas and slowed the southward flow of the floodwaters toward Bangkok.

The third phase of the flood started in mid-October and lasted through December 2011. By mid-October, major industrial estates in the Central Region were flooded. The floods in Ayutthaya, north of Bangkok, peaked in October, and flood barriers around seven industrial estates failed. These industrial estates flooded for the first time in their history, disrupting supply chains throughout the world (e.g., cars, disk drives, and other electronic components). Some industrial estates were under as much as 3 m of water. By late October, over 5.5% of Thailand was under water, and floodwaters entered greater Bangkok. By mid-November, 5.3 million people were affected, over 8% of the total population of Thailand [*World Bank*, 2012]. Efforts to protect the central business district were successful, but districts in northern Bangkok and the provinces of Nonthaburi and Pathum Thani in the greater Bangkok metropolitan area were hit especially hard. Transportation networks were severely affected; several main highways and the city's secondary airport were forced to close. In many districts of greater Bangkok, floodwaters rose to a maximum of 2–3 m and remained for 2–3 months. In an attempt to drain their neighborhoods, frustrated residents tore down flood barriers, sending floodwaters into other parts of the city. By late November and early December, the floodwaters had receded in many areas, but some places remained flooded until mid-January 2012.

The inability of the two major dams in the Chao Phraya basin, Bhumibol and Sirikit, to mitigate the severity of the 2011 flood has been the subject of much public discussion and debate in Thailand. Some argued that the dams had been mismanaged since a large quantity of water was stored at the beginning of the monsoon, resulting in large subsequent releases after the heavy rains occurred in the late summer and fall. Early in the 2011 monsoon season, these dams held large amounts of water in storage. During the 2010 monsoon season, rainfall had been low, and dam levels were at record lows in June 2010 [*Asian Correspondent*, 2011a]. The Bhumibol Dam was filled to capacity in only 3 months, from August to October 2011 [*Asian Correspondent*, 2011b]. Once the Bhumibol Dam reached capacity, heavy rains continued and releases from the dam had to be increased. Of course, had the monsoon rains in 2011 again been low as in 2010, the opposite situation would have occurred. Reservoir managers would have been criticized if they had released too much water early in the season to minimize flood control risks, and then had too little water in storage to meet irrigation needs.

Based on flood property loss data from 1950 to 2010, Thailand has had the highest average annual property losses from floods of any country in Southeast Asia and ranks 34th in the world (Emergency Disasters Database—EM-DAT 2011). In Thailand, expected annual property losses from floods are USD 2.74 per capita, compared to USD 1.62 per capita in Malaysia and less than USD 0.11 per capita in Singapore. However, Thailand's flood mortality risk (0.11 deaths per 100,000 population per year) is below the world average of 0.86 deaths per 100,000 population per year.

Thailand's relatively low flood mortality risk is partly because residents in flood-prone areas of the Chao Phraya River Basin and other parts of the country have coped with regular flooding for centuries. People expect floods and have adapted to reoccurring flood events. Historically, people in flood-prone areas have constructed their homes on stilts and built two-story housing so that they can move their possessions and themselves up to the second floor during floods. Although the rural areas in the northern Chao Phraya basin are especially used to regular flooding, severe flooding in Bangkok is more infrequent. Large parts of Bangkok were inundated for 2 months in 1942 and for 5 months in 1983. Before the 2011 flood hit the

10.1002/2014WR015982

Greater Bangkok Metropolitan Area, the last severe flood was in 1995. However, in 2006, other parts of Thailand experienced severe flooding. Bangkok was not affected because local rainfall was not excessive, and the city's flood protection system of canals, embankments, and pumps was able to contain the floodwaters. In 2011, many Bangkok residents (mistakenly) used the 1995 flood as a benchmark of the worst that could happen in their neighborhood.

A combination of factors has led to increasing flood risks in Thailand. Increased agricultural cultivation in the upstream portions of the Chao Phraya Basin has caused deforestation, which has resulted in a decrease in flood retention areas. Urban growth in the lower Chao Phraya basin has reduced the ability to disperse floodwaters over agricultural lands in a flooding emergency. Many canals in and around Bangkok have low gradients and are filled with silt and debris, reducing the ability of the drainage system to remove floodwaters. Moreover, the greater Bangkok area is one of the locations in Southeast Asia most vulnerable to climate change [*Yusuf and Francisco*, 2010]. A 30% increase in flood-prone area is expected in greater Bangkok by 2050 due to increased precipitation and land subsidence of 5–30 cm [*Panya Consultants*, 2009]. Most of the increase in flood-prone area is expected in western Bangkok, where flood control infrastructure is especially inadequate.

During the 2011 flood, more than 680 people were killed nation wide, and 6 million hectares (nearly 12% of the surface area of the country) were flooded over the 4 month period from September to December [*A.M. Best*, 2012]. The 2011 Thailand flood was the fifth most costly insured loss event worldwide in the last 30 years [*A.M. Best*, 2012]. The World Bank estimated economic losses and damages at THB1.4 trillion (USD 47 billion, or about USD 700 per capita) [*World Bank*, 2012]. Thailand's annual GDP growth in 2011 declined from midyear estimates of 4.0% to 2.9%.

In the past, a major focus of flood damage mitigation has been on early warning systems to alert people of the imminent risk of flood events, and the hope has been that people could act effectively on this information before the flood arrives to reduce the costs they are likely to incur. The 2011 Bangkok flood was the first major flooding disaster to hit a population center in South or Southeast Asia in which many people were connected to the web with smart phones and other types of internet access. The flood unfolded slowly, and most households in greater Bangkok had access to information from multiple sources—television, radio, internet, friends and neighborhood leaders, and local and national governments (television was the most important information source for the majority of households). The problem for most households was not lack of early warning, but rather how to assess the quality and accuracy of conflicting information from different sources. This is a relatively new flood management problem, but one that will grow in importance, especially for urban residents connected to global media channels.

The ways in which households could act effectively on the information they received in order to reduce flood losses were limited. Some households in Bangkok managed to move their automobiles to higher ground (e.g., elevated motorways), and some of their possessions to the second story or roof of their dwellings. The current transportation infrastructure will not support a mass exodus, and there are few places for this many people to go. Moreover, as in many types of disasters, some people will not want to leave their homes, due in part from a desire to protect their possessions from theft.

3. Description of the Study Sites, Sampling, and Fieldwork

The study was conducted in three provinces of the Greater Bangkok Metropolitan Area: Nonthaburi, Pathum Thani, and Bangkok. We purposively selected three districts, one in each province, that were among the hardest hit by the 2011 flood: *Bang Bua Thong* District (Nonthaburi); *Klong Luang* District (Pathum Thani); and *Don Mueang* District (northern Bangkok). Within each of these three districts, we purposively selected two middle-income neighborhoods and two low-income neighborhoods, for a total of 12 neighborhoods.

The depth of the floodwaters at its highest level (about 2 m) was comparable for the study areas in the three districts (Table 1). The duration of flood (about 2 months) for the three study areas was also similar. The three districts differed, however, with respect to the speed with which the floodwater rose. In *Bang Bua Thong* (Nonthaburi), the floodwaters rose to their maximum level within 24 h. In *Klong Luang* (Pathum Thani), the floodwaters rose more gradually, 0.5 m in 1 week. The *Don Mueang* District of Bangkok flooded before the other two study sites and water rose at a moderate pace (0.8 m within 24 h).

Table 1. Profile of the Study Area

	Bang Bua Thong, Nonthaburi	Don Mueang, Bangkok	Klong Luang, PathumThani
History of flooding	Major flood in 1995	Did not flood in 1995	Flooded in 1995
When flood arrived	Mid-October	Late October	Mid-October
Speed of rising water	Fast (nearly 2 m within 24 h)	Moderate (80 cm within 24 h)	Slow (50 cm within 1 week)
Median depth of flood (on road)	1.5 m (range: 0.5–3 m)	1.5 m (range: 0.5–3 m)	0.6 m (range: 0.5–2 m)
Population of study area districts[a]	201,254	166,951	120,766
Distance from Central Business District	39 km	30 km	45 km
Elevation (meters above sea level)	0 m	0.5–1 m	2.30 m
Number of districts flooded	4 out of 6	36 out of 50	7 out of 7

[a]Note: Population of Nonthaburi province =1,135,299; Bangkok = 5,668,502; and Pathum Thani =1,026,934. Source: Department of Provincial Administration.

In each of the three districts, we tried to interview 200 respondents; the total target sample size was thus 600 respondents. Within each of the 12 residential areas, we set a quota of 50 respondents to be interviewed. To the extent practicable, we tried to distribute the 50 respondents in each residential area across the entire spatial area of the neighborhood. For example, for one of the two middle-income neighborhoods in *Bang Bua Thong* (Nonthaburi), we selected the Chollada Housing Estate and the Pattaraniwetr neighborhood. The former is a large housing estate with more than 1000 households. The low-income neighborhoods in all three districts were much smaller. In these neighborhoods, we had to interview almost everyone we could find in order to meet our quota of 50 households. In this paper, neighborhoods are classified as "low income" or "middle income" depending on the socioeconomic status of the majority of the households living there (including the characteristics of their housing). The terms "poor" and "nonpoor" are used to refer to specific households. Survey data collected from households in the sample are used to designate individual households as "poor" or "nonpoor." Not all households living in a "low-income" neighborhood are poor. In fact, only about half of the households in low-income neighborhoods were classified as poor.

In all three districts, during the first round of the survey the response rates were higher in low-income neighborhoods than in middle-income neighborhoods. For the low-income neighborhoods in *Bang Bua Thong* District (Nonthaburi), the response rate was 93% compared to 68% in the middle-income neighborhoods (Chollada and Pattaraniwetr). In the *Klong Luang* District (Pathum Thani), the response rate was of 97% and 61% for the low-income and middle-income neighborhoods, respectively. For *Don Mueang* District (Bangkok), response rate was 91% for the low-income group and 61% for the middle-income group. The locations of all the households interviewed were geocoded. We do not claim that our final sample is representative of households either in greater Bangkok or within the three provinces. We do believe, however, that sample households span a wide range of socioeconomic and housing conditions in some of the most severely flooded neighborhoods in different parts of the city.

To assist with question selection and design, six pilot interviews were conducted during which respondents were told to "think out loud" as they answered the questions. This helped us to better understand the respondents' experience with the flood and how they interpreted the questions. Before the first round of the survey was implemented, the survey instrument was pretested with 36 respondents. During the actual first-round survey implementation four field staff supervised 18 enumerators. All of the first-round interviews were conducted during January and February 2012, soon after the floodwaters had receded from respondents' houses. On average, interviews lasted 40–45 min. Informed consent was received from all respondents. Before the second round of interviews was conducted in January 2013, the questionnaire underwent further pretesting and refinement.

4. Definitions, Calculations of Economic Costs Incurred by Households, and Modeling Strategy

4.1. Terminology

There is no standardized methodology to estimate the economic costs of floods [*White et al*., 2001]. Nor is there a standardized terminology used to describe the adverse consequences of floods. When estimating the economic consequences of a flood event, one should consider the effects on households' well being in three time periods, or stages of the event—(1) before the flood arrives; (2) during the flood, (3) after the

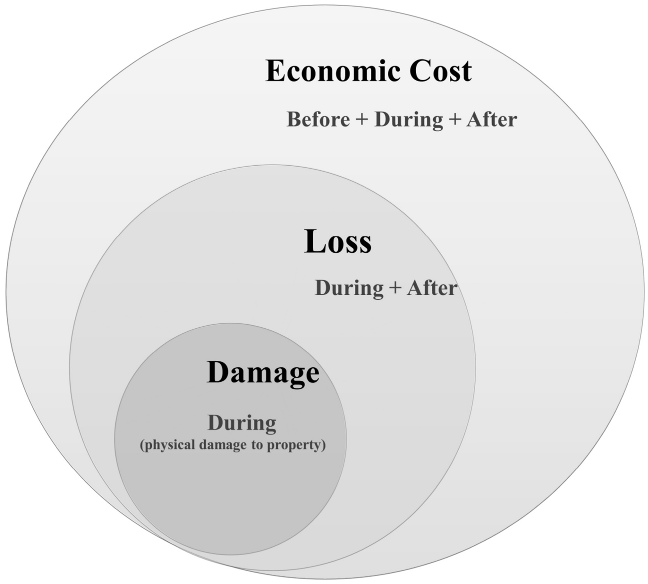

Figure 1. Economic cost, loss, and damage categories.

floodwaters recede. We use the term "economic costs" as inclusive of the negative consequences of a flood in all three of these stages. We refer to the costs incurred before the flood arrives (stage 1) as ex ante costs; and costs incurred after the flood hits as ex post costs during the flooding event and after the floodwater recede, (stages 2 and 3, respectively).

We use the terms "damages" and "losses" to refer to the ex post economic costs of floods. We follow *Krutilla* [1966] and use the term "damages" to refer to the physical impairment of structures and other property. We use the term "losses" to refer to all ex post economic costs. "Damages" are thus a subset of "losses," and "losses" are a subset of "economic costs" (Figure 1).

Households make financial expenditures before the flood to reduce economic losses after the flood arrives. They also make financial expenditures after the flood has hit in order to deal with the economic losses they have suffered. Both types of financial expenditures are components of the total economic costs of the flood event. Preventative (ex ante) expenditures made before the flood arrives are real costs to the household, but are not best conceptualized as "damages" or "losses." Expenditures made after the flood hits to deal with the consequences are one monetary measure of the magnitude of the losses incurred by the household, but such expenditures are not a comprehensive or complete measure of the ex post loss incurred because residual losses may remain even after financial expenditures have been made to reduce the losses (damages).

Some of the engineering literature on the costs of floods separates ex post costs incurred into tangible and intangible components based on the extent to which the consequences of the flood can be expressed in monetary terms *Dutta et al.* [2003]; [*Smith and Ward*, 1998; *Thieken et al*., 2005]. Tangible losses include damages to property, buildings, and business interruptions that can be expressed in financial terms. Intangible losses are more challenging to monetize and include, for example, mortality and psychological suffering. However, over the past few decades, nonmarket valuation techniques (both revealed and stated preference methods) have experienced continual methodological improvements, and losses that once were considered impossible to quantify in monetary terms (and thus "intangible") may now be counted as "tangible" and expressed in monetary, welfare-theoretic terms [*Hanemann*, 1992; *Smith*, 2004]. For example, in the past, some studies of flood losses considered mortality and morbidity losses to be intangible, but such health effects are now often expressed in monetary terms *Dutta et al*. [2003].

Another distinction sometimes made is between direct and indirect economic costs. Direct economic costs often refer to easily monetized costs; often they can be approximated by the financial expenditures households make to deal with the negative consequences of the flood, such as repair and rehabilitation of a flooded house. Indirect economic costs may include the time spent on preventative and clean-up activities. Often indirect costs can be expressed in monetary terms, but market prices are not readily available for their estimation. Direct tangible economic losses would include damage to buildings and property, while indirect tangible losses would include disruptions in trade and business activity. Direct damages may be considered to involve physical contact of floodwater with people and property. Much of the flood loss literature focuses on direct tangible damages to property [*Merz and Thieken*, 2004]. Many studies, as well as insurance claims for flood losses, do not include indirect tangible losses such as depreciated property and business values [*White et al*., 2001]. For households with insurance coverage, insurance claims can sometimes be used as a measure of some components of property damages.

In this study, we classify economic costs using three distinctions:

1. Timing: before the flood arrives (ex ante); during the flood (ex post), and after the floodwaters recede (ex post),
2. Direct and indirect,
3. Health-related and nonhealth-related.

We do not attempt to classify economic costs as "tangible" versus "intangible" costs. Nor do we report damages separately from losses, although we do use both these two terms (as defined above). Finally, we do not report "financial expenditures" separately; but these are closely associated with our category of "direct costs."

4.2. Calculation of Household Economic Costs

We used the data obtained from the first and second rounds of the household survey described above and other data obtained from secondary sources to estimate the economic costs that sample households incurred as a result of the 2011 Thailand flood. Our estimates of the economic costs include both ex ante (preflood) expenditures and other costs incurred to reduce ex post economic losses (e.g., damages to property, health, and forgone income incurred during and after the flood). We do not include residual damages, i.e., property damages that households do not plan to repair after the flood event, or any property damages that remain after repairs and rehabilitation efforts are complete.

We report estimates for five categories of flood-related economic costs: (1) ex ante preventative costs; (2) ex post nonhealth-related losses during the flood; (3) ex post nonhealth-related losses after the flood, (4) ex post health-related losses both during and after the flood; and (5) household contributions to community (both ex ante and ex post). We further report the direct and indirect costs associated with each of these five components. In addition, some households received compensation from government and other sources, which is a transfer payment to the household that reduces the total household costs. A very small number of sample households may have received payments from insurance companies for the property damages they incurred. We did not collect this information in the surveys because (1) very few households had coverage; and (2) these payments would be transfers (i.e., our estimates of property losses represent the real resource costs). Table 2 presents the various items included in the cost estimates for the direct and indirect costs for each of these five categories. Direct costs were comprised of expenditures for hired labor and materials to prepare, cope, and recover from the flood. Indirect costs included own labor, volunteer labor, and opportunity cost of time due to missed work, increased travel time, and caring for sick household members. For the survey respondent, indirect costs were calculated as the product of a monetary value of lost productivity, days of work missed, and increased travel time to work and home. The value of lost productivity was estimated based on the respondent's self-reported income. For all other household members, we assumed that the value of lost time was the minimum daily wage rate in Thailand (THB 300, USD 9.7).

Preventative costs comprised ex ante expenditures and self-supplied labor to prepare for the arrival of the floods and hopefully mitigate losses. Households parked cars in alternate locations and purchased goods to prepare for the flood such as construction materials, sandbags, and small boats. Nonhealth related economic costs during the flood included expenditures for alternative shelter, materials to cope with flooding, emergency food and drinking water, and increased travel costs. Foregone income due to days of worked missed was also included for respondents who were wage workers, self-employed, or business owners. Direct nonhealth-related losses during the flood included coping costs (shelter, supplies, etc.), increased expenses to commute to work and home, and increased food expenditure. Indirect nonhealth-related losses during the flood included increased travel time to work and home as well as foregone income due to not being able to commute to work.

Ex post nonhealth-related economic losses included expenditures for car repairs and to repair, clean, and replace housing and other property damage. Ex post health-related costs were based on the information reported by survey respondents about flood-related diseases experienced by household members. Expenditures on medicine and doctor visits were included in direct costs, while indirect costs were comprised of foregone income of the patient and caretakers. As for indirect nonhealth-related losses, respondent's time was valued based on self-reported income, and for sick household members other than the survey respondent, time was valued at the minimum daily wage rate of THB 300 (USD 9.7).

Table 2. Components of Total Economic Costs Incurred by Households

Cost Component	Equation
Total Economic Cost	= A+B+C+D+E
A. Preventative Costs (Ex ante)	
Direct	
Hired labor	= Number of days * THB 300 per day[a]
Materials and Activities	
Parking car in alternate location	
Preventative materials (sandbags, pumps, construction materials)	= total cost/2
Indirect	
Own labor	= Number of days * monthly income/22 days
Volunteer labor	= Number of days * THB 300 per day
B. During-Flood Economic Loss (Nonhealth-related)	
Direct	
Preparation expenditures	
Alternate accommodation (shelter)	
Kitchenware, food supplies, water storage	
Boats, clothing, plastic trousers	
Other (sandbags, pumps, construction materials)	= total cost/2
Increased work commute costs	= change in work commute costs * number flooded days
Increased cost to travel home	= change in home travel costs * number of trips home
Increased food cost	= change in weekly food costs * flood duration
Indirect	
Increased travel time to work	= change in commute time * (flood duration*(5/7) – government holiday – days of work missed) * (monthly income/22 days)
Increased travel time to house	For each household member: change in time to travel home * number of trips * opp cost of time[b]
Foregone income[c]	
C. After-Flood Economic Loss (Nonhealth-related)	
Direct	
Car Repairs	
Housing and belongings damage	
Hired labor for moving + repair	= Number of days * THB 300 per day
Cost to repair, clean, replace	
Indirect	
Housing and belongings damage	
Own labor for moving + repair	= Number of days * monthly income/22 days
Volunteer labor for moving + repair	= Number of days * THB 300 per day
D. Health-Related Cost	
Direct	
Doctor visits	
Medicine	
Indirect	
Foregone income of patient[c]	= Number of days * opp cost of time[b]
Foregone income of care taker	= Number of days * THB 300 per day
E. Household Contributions to Community	
Direct	
Cash contribution	
Volunteer time	= Number of days * THB 300 per day

[a]Minimum daily wage is THB 300. In September 2012, USD 1 = 30.8 Thai baht.
[b]Opportunity cost of time for respondent is income, otherwise THB 300 per day is assumed.
[c]Foregone income only applies to wage workers, self-employed, or business owners.

In addition, some households contributed to community flood efforts, either through cash contributions or volunteer time. These contributions are included in total household costs. Most households received government compensation for flood damage. This compensation is a transfer from government to households, and is reported separately from total household costs. Some households were able to generate new income during the flood, by offering needed goods and services such as prepared food and boat transport. The net economic costs experienced by a household are the total costs minus any compensation received or new income generated.

In summary, our estimates of the costs incurred by households in the 2011 Bangkok flood go far beyond the typical engineering estimates of financial damages to households' dwellings and contents. Notably, they include

1. Not only ex post costs, but also ex ante expenditures;
2. Health-related costs;
3. Productivity losses due to lost work and illness; and
4. Households' coping costs for alternative shelter and supplies when they were forced to leave their homes.

Households' payments for flood insurance can be considered one measure of the perceived ex ante costs of flooding risks. We have not included these payments because (1) few households (less than 1%) in Bangkok had flood insurance at the time of the 2011 flood [*Orie and Stahel*, 2013]; (2) the policies were subsidized, and thus not a good measures for estimating expected real costs; (3) information was not collected on insurance company payments for property damage. Including insurance payments to households as a cost component would result in double counting real resource costs.

Our household cost estimates from the 2011 Bangkok flood can be used to estimate the benefits of flood mitigation strategies when such interventions will reduce such costs. These measures of potential "avoided costs" are conceptually similar to the use of "coping costs avoided" as welfare-theoretic benefits from water and sanitation investments [*Pattanayak et al*., 2005], and avoided cost-of-illness estimates as measures of the benefits of health interventions in the public health field [*Poulos et al*., 2011]. Of course, the costs borne by households are not the total economic costs of the flood event. For example, they do not include foregone production or property damages in the flooded industrial districts of Bangkok.

4.3. Modeling Strategy: Factors Associated With Preventative Costs and Household Economic Losses

We used regression analysis to estimate the association between preventative costs and whether the household received a provincial-level flood warning, and respondent, household, and neighborhood characteristics. Our model specification was

$$PreventCost = \beta_0 + \beta_1 \; warning + \gamma_j X_j + \mu_k H_k + \omega_m V_m \tag{1}$$

where

PreventCost = total preventative costs incurred by household;

warning = household received a provincial-level flood warning or not;

X_j = personal characteristic *j* (e.g., education level);

H_k = household characteristic *k* (e.g., annual expenditure, number of cars owned);

V_m = neighborhood controls.

We expected information in the form of provincial-level flood warnings to increase the magnitude and effectiveness of preventative actions. However, in addition to being aware of the flood risk, households can only take carefully considered preventative actions if they are informed about the cost and effectiveness of measures to mitigate flood losses [*Thieken et al*., 2005; *Grothmann and Reusswig*, 2006]. Perceived flood risk is not only influenced by flood warnings, but also the frequency of past events, how recent the previous flood was, and personal risk tolerance. Such variables are not considered in our model. Nor did we include variables related to previous flood experience due to correlation with household income and neighborhood. Higher-income households tended to have shorter residence periods in their current homes and therefore tended to have less previous flood experience. The household decision to undertake flood mitigation measures is also influenced by expectations regarding responsibility for flood control and response, i.e., whether these responsibilities lie more with individual households or the government.

In order to determine which factors were associated with losses incurred during and after flooding, ex post household economic losses were regressed on characteristics of the respondent, the household, and the neighborhood. We also included depth of flood and whether the household received a provincial-level flood warning. Our model specification was:

Table 3. Summary Statistics of Regression Variables (Obs = 469)

	Definition	Mean	Std Dev	Min	Max
Preventative cost	Expenditures on preventative measures (in THB)	8235	14,904	0	180,773
Ex post losses	Total household losses during and after the flood (in THB)	151,499	187,530	400	1,511,432
Total flood losses	Total costs, before, during, and after flood (in THB)	162,050	192,084	1423	1,519,323
Annual household expenditures	Total household expenditures per year (in THB)	261,381	192,006	30,600	1,200,000
Cars owned	Number of cars owned	0.9	1	0	5
Education Level					
Elementary or less	Dummy variable = 1, if respondent had elementary school education or less	0.38	0.49	0	1
High School or Vocational	Dummy variable = 1, if respondent had high school or vocational education	0.33	0.47	0	1
College or more	Dummy variable = 1, if respondent had college education or more	0.29	0.45	0	1
Flood warning (district specific)	Dummy variable = 1, if household received province-specific flood information	0.83	0.37	0	1
Flood depth (first floor)	Flood depth on first floor of house (in cm)	107	57	0	300
Neighborhood					
YaJai (Nonthaburi, low income)	Dummy variable = 1, if household lives in this neighborhood	0.08	0.28	0	1
FangNean (Nonthaburi, low income)	Dummy variable = 1, if household lives in this neighborhood	0.09	0.29	0	1
Chollada (Nonthaburi, middle income)	Dummy variable = 1, if household lives in this neighborhood	0.09	0.28	0	1
Pattaranivate (Nonthaburi, middle income)	Dummy variable = 1, if household lives in this neighborhood	0.07	0.26	0	1
Ruamjairuk (Bangkok, low income)	Dummy variable = 1, if household lives in this neighborhood	0.07	0.25	0	1
Promsumrit (Bangkok, low income)	Dummy variable = 1, if household lives in this neighborhood	0.09	0.29	0	1
Saraneepark (Bangkok, middle income)	Dummy variable = 1, if household lives in this neighborhood	0.13	0.33	0	1
Chudapa (Bangkok, middle income)	Dummy variable = 1, if household lives in this neighborhood	0.02	0.13	0	1
Bualuang (Pathum Thani, low income)	Excluded neighborhood, dummy variable=0 for all households	0.10	0.30	0	1
Suksombun (Pathum Thani, low income)	Dummy variable = 1, if household lives in this neighborhood	0.10	0.30	0	1
PhinicPark (Pathum Thani, middle income)	Dummy variable = 1, if household lives in this neighborhood	0.09	0.29	0	1
Phapinjad (Pathum Thani, middle income)	Dummy variable = 1, if household lives in this neighborhood	0.08	0.27	0	1

$$Flood\ \ Loss=\beta_0\ +\ \beta_1\ warning+\ \beta_2 flood\ \ depth\ +\ \gamma_j X_j+\mu_k H_k+\omega_m V_m+\varepsilon \tag{2}$$

where

Flood Loss = total ex post flood loss (costs incurred during and after the flood);

warning = provincial-level flood warning received;

flood depth = depth of flood water (first floor of house);

X_j = personal characteristic *j* (e.g., education);

H_k = household characteristic *k* (e.g., annual expenditure, number of cars owned);

V_m = neighborhood controls.

The association between receiving a provincial-level flood warning and ex post losses was expected to be negative since informed households should be better able to prepare and cope with the flood. A household's ability to respond to a provincial-level flood warning will be constrained by its income. A similar model was specified for total flood costs (preventative costs plus flood loss):

$$Total\ \ Flood\ \ Cost=\beta_0\ +\ \beta_1\ warning\ +\ \gamma_j X_j+\mu_k H_k+\omega_m V_m+\varepsilon \tag{3}$$

Table 3 provides definitions and summary statistics for all variables included in the preventative expenditure, ex post flood loss, and total flood cost models (i.e., equations (1–3)). Preventative costs were excluded from the ex post loss model (equation (2)) due to endogeneity concerns. We do not have good, household-specific measures of either the objective or perceived flood risk. Therefore, there is the possibility that households with higher preventative costs knew that they were at greater risk, especially in Klong Luang, and thus spent more ex ante on mitigation strategies. Since preventative costs are a function of flood risk, and people act on perceived flood risk, establishing a causal relationship between preventative expenditures and ex post losses is challenging. This is a common problem in flood cost estimation studies, and we do not claim to have a compelling identification strategy. Nevertheless, we believe that the association between preventative expenditures and ex post losses is still of interest.

5. Results

5.1. Socioeconomic Profile of Respondents

Respondents were located in both middle-income neighborhoods (220 households) and low-income neighborhoods (249 households). The 220 respondents living in middle-income neighborhoods were mostly self-employed or employed by businesses in the private sector. The average monthly expenditure of middle-income households (estimated using data from the second-round of the survey) ranged from THB 50,843 in Klong Luang to THB 82,053 in Bang Bua Thong to THB 156,391 in Don Mueang.

Most respondents in low-income neighborhoods were wage workers; about a quarter were self-employed. The average monthly expenditure of households in low-income neighborhoods of *Bang Bua Thong* and *Don Mueang* (THB 11,643 and THB 12,412, respectively) were significantly lower than in *Klong Luang* district (THB 15,238). The years of education and household expenditures of the respondents in middle-income neighborhoods were significantly higher than of respondents in low-income neighborhoods.

Almost all respondents in lower-income neighborhoods lived in one-story houses. In general, households in low-income neighborhoods have lived longer in their homes than households in the middle-income neighborhoods. The average length of stay for households in low-income neighborhoods was over 25 years. The average length of stay in middle-income neighborhoods ranged from 7 years in *Don Mueang* and *Klong Luang* to 15 years in *Bang Bua Thong*. Self-reported house values for households in middle-income neighborhoods range from THB 1.5 million (USD 50,000) in *Klong Luang* to THB 3.5 million (USD 113,000) in *Bang Bua Thong* and THB 4.7 million (USD 151,000 USD) in *Don Mueang*. For households in low-income neighborhoods, house values in *Klong Luang* and in *Don Mueang* averaged about THB 295,000 (USD 9590) and THB 317,000 (USD 10,280), respectively. Average house values for *Bang Bua Thong* were slightly higher (THB 368,000; USD 11,946).

5.2. Total Economic Costs From the 2011 Flood

Median total household costs were about THB 95,138 (USD 3089) for the 469 households included in the sample for whom both rounds of interviews were completed (Table 4). Nearly 14% of households had economic costs in excess of THB 300,000, although less than 5% of households had over THB 600,000. The cumulative frequency distribution of total household costs (Figure 2) shows how total economic costs varied dramatically across households—even in these neighborhoods most severely affected by the 2011 Bangkok flood. About 22% of households had economic costs over THB 200,000. Households with losses over THB 200,000 tended to have more property at risk (e.g., more cars and more valuable homes) and to have higher monthly expenditures. These households were also more likely to live in middle class neighborhoods in *Bang Bua Thong* (Nonthaburi), where floodwaters rose quickly.

For most households, direct costs were greater than indirect costs (Figure 2). As a proportion of annual household expenditure, median costs were 48% of annual expenditure. As a percentage of annual household income, median costs were 26%. A considerable number of households incurred high costs relative to annual expenditure (Figure 3). About 18% of households had costs that were equivalent to or greater than their annual expenditure, while only 2% of households had costs that were equivalent to or greater than twice their annual expenditure.

The cost of house repairs was surprisingly low given the depth and duration of the floods (Table 4). Median house repair costs as a percent of house value were 2% (mean of 8%). Most houses incurred little structural damage.

5.3. Composition of Economic Costs

The total household economic cost was subdivided into five components: (1) ex ante preventative costs; (2) ex post nonhealth-related losses during the flood; (3) ex post nonhealth-related losses after the flood; (4) ex post health-related losses both during and after the flood; and (5) household contributions to community (both ex ante and ex post). The largest component was the ex post nonhealth-related losses after the flood, which accounted for 66% of mean household total cost, followed by nonhealth losses during the flood (27% of mean total cost) (Figure 4a).

Median nonhealth-related losses after the flood were about THB 51,700 (USD 1680). Damage to homes and belongings was by far the largest component of ex post economic loss. Particularly high losses were incurred for replacement of furniture, cleaning of home, and replacement of electrical appliances.

Table 4. Summary Statistics of Economic Cost Components (469 Households)

		Nonthaburi			Bangkok			Pathum Thani					
		All	Middle Income	Low Income	All	Middle Income	Low Income	All	Middle Income	Low Income	Above 150% Poverty Line[a]	Below 150% Poverty Line[a]	Total
Cost Component	Obs	155	73	82	143	68	75	171	79	92	359	110	469
A. Preventative costs (ex ante)	Median	2500	5682	1250	3409	9795	2255	5114	8159	2386	5273	1893	3409
	Mean	5861	9181	2905	11,441	17,756	5715	7707	12,126	3912	9756	3272	8235
	Std Dev	8679	10,914	4308	22,866	27,305	16,075	9614	11,287	5653	16,553	4610	14,904
	Max.	54,091	54,091	20,455	180,773	180,773	130,046	58,175	58,175	41,364	180,773	30,395	180,773
B. During-flood economic loss	Median	27,857	28,900	27,678	17,884	23,113	17,600	30,000	34,550	26,259	26,761	19,304	25,343
	Mean	49,546	69,890	31,435	38,859	55,773	23,524	42,305	52,416	33,622	48,714	27,113	43,647
	Std Dev	92,294	128,781	27,352	70,776	95,318	29,749	50,806	65,470	31,354	81,101	26,565	72,661
	Max.	817,932	817,932	123,015	532,712	532,712	211,158	370,842	370,842	155,257	817,932	152,500	817,932
C. After-flood economic loss	Median	56,391	165,088	24,649	81,200	177,550	35,476	37,867	55,473	28,389	69,652	21,920	51,709
	Mean	125,491	228,109	34,136	150,891	261,411	50,685	54,924	75,897	36,915	131,018	30,774	107,507
	Std Dev	172,291	205,629	30,196	183,481	211,949	50,265	61,023	78,254	31,589	165,756	29,480	151,749
	Max.	1,051,100	1,051,100	123,927	850,000	850,000	278,580	546,500	546,500	154,464	1,051,100	155,800	1,051,100
D. Health-related loss[b]	Median	0	0	0	0	0	0	0	0	0	0	0	0
	Mean	584	652	522	199	279	126	250	141	343	336	372	345
	Std Dev	3916	2802	4707	1473	2072	515	1291	788	1600	2633	2105	2517
	Max.	42,630	18,500	42,630	17,000	17,000	3198	13,500	6700	13,500	42,630	17,000	42,630
E. Household contributions to community	Median	0	0	0	0	900	0	600	1500	0	0	0	0
	Mean	1383	932	1784	1832	2547	1184	3568	4027	3174	2432	1939	2316
	Std Dev	3799	2874	4444	4024	3348	4475	8123	7678	8508	6100	5099	5879
	Max.	24,000	20,100	24,000	25,200	15,000	25,200	53,700	39,900	53,700	53,700	36,900	53,700
Total economic cost	Median	93,998	220,100	59,863	123,705	246,838	65,923	80,597	111,125	63,036	121,896	52,123	95,138
	Mean	182,864	308,765	70,782	203,222	337,767	81,234	108,753	144,606	77,966	192,256	63,470	162,050
	Std Dev	229,017	282,008	44,972	221,028	252,120	66,913	92,607	114,338	52,359	209,018	45,987	192,084
	Max.	1,519,323	1,519,323	229,824	1,251,385	1,251,385	385,721	570,467	570,467	247,691	1,519,323	247,691	1,519,323
Direct	Median	65,150	180,760	34,381	81,843	218,879	36,761	47,036	58,329	38,225	80,200	30,807	59,000
	Mean	134,381	238,529	41,663	159,541	279,556	50,727	62,759	81,589	46,590	139,874	37,822	115,939
	Std Dev	174,986	208,471	33,260	189,726	213,708	49,864	63,509	82,150	34,324	169,797	33,501	155,530
	Max.	1,088,700	1,088,700	148,529	941,000	941,000	279,050	556,900	556,900	171,820	1,088,700	176,800	1,088,700
Indirect	Median	23,826	20,314	24,604	20,518	21,939	17,545	29,191	40,085	25,940	27,158	18,178	24,545
	Mean	48,484	70,236	29,119	43,681	58,212	30,506	45,994	63,017	31,376	52,382	25,648	46,112
	Std Dev	95,747	134,165	24,968	72,799	95,491	39,292	52,738	67,169	29,345	83,724	25,207	75,091
	Max.	807,023	807,023	111,130	547,055	547,055	216,364	331,237	331,237	167,159	807,023	167,159	807,023
Total economic cost (% annual expenditures)	Median	0.58	0.79	0.52	0.55	0.59	0.48	0.39	0.41	0.38	0.48	0.53	0.48
	Mean	0.78	0.99	0.60	0.71	0.88	0.56	0.46	0.46	0.46	0.65	0.60	0.64
	Std Dev	0.6	0.7	0.4	0.6	0.7	0.4	0.3	0.3	0.3	0.5	0.4	0.5
	Max.	2.8	2.8	2.6	2.8	2.8	1.9	1.6	1.5	1.6	2.8	2.6	2.8
Total economic cost (% annual income)	Median	0.32	0.27	0.34	0.25	0.22	0.27	0.25	0.25	0.25	0.27	0.25	0.26
	Mean	0.44	0.45	0.43	0.30	0.28	0.31	0.29	0.26	0.32	0.35	0.31	0.34
	Std Dev	0.4	0.4	0.5	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.3
	Max.	3.0	2.3	3.0	1.4	1.1	1.4	1.6	0.9	1.6	3.0	1.4	3.0
Dwelling-related cost (% of house value)	Obs	143	68	75	127	64	63	148	76	72	323	95	418
	Median	0.02	0.02	0.03	0.02	0.01	0.04	0.02	0.01	0.05	0.02	0.05	0.02
	Mean	0.07	0.03	0.11	0.08	0.02	0.14	0.07	0.03	0.12	0.06	0.12	0.08
	Std Dev	0.12	0.06	0.15	0.17	0.03	0.22	0.14	0.04	0.19	0.12	0.20	0.14
	Max.	0.7	0.4	0.7	0.9	0.2	0.9	1.1	0.2	1.1	0.9	1.1	1.1
F. Compensation	Median	25,000	25,000	25,000	25,000	24,150	25,000	23,000	25,000	21,000	25,000	24,250	25,000
	Mean	24,465	25,588	23,465	21,033	20,202	21,787	22,263	24,430	20,402	22,973	21,450	22,616
	Std Dev	9845	13,602	4204	7415	8646	6050	8879	10,216	7088	9536	6279	8897
	Max.	125,000	125,000	28,700	55,000	55,000	25,000	89,000	89,000	40,000	125,000	35,000	125,000
New income during flood	Median	0		0	0		0	0	0	0	0	0	0
	Mean	425		804	34		65	1347	2253	568	739	326	642
	Std Dev	2786		3801	410		566	8001	11,168	3370	5623	2895	5116
	Max.	30,000		30,000	4900		4900	80,000	80,000	30,000	80,000	30,000	80,000
Net economic cost	Median	68,998	187,029	35,863	100,941	225,838	46,277	56,664	84,125	44,361	93,987	31,711	71,789
	Mean	152,460	273,013	45,138	182,154	317,565	59,382	84,618	117,402	56,466	166,004	41,395	136,778
	Std Dev	221,905	274,690	42,326	220,990	251,129	66,986	91,797	114,664	52,327	206,113	46,154	189,174
	Min	(13,361)	6560	(13,361)	(21,445)	30,207	(21,445)	(33,347)	(33,347)	(26,138)	(33,347)	(26,138)	(33,347)
	Max.	1,496,323	1,496,323	196,180	1,226,385	1,226,385	360,721	547,667	547,667	222,691	1,496,323	222,691	1,496,323

[a] Poor households were defined as having expenditures below 150% of the national poverty line. The national poverty line was expenditures of THB 1443 per person per month in 2007 [United Nations Development Program (UNDP), 2010]. Adjusting for inflation, this is equivalent to THB 1618 per person per month in 2011. Households with expenditures under THB 2427 per person per month were considered to be poor.

[b] In addition, two deaths were reported. Although not included in total loss estimates, using VSL, this loss amount is estimated to be between USD 2.2 and 2.8 million (2012 USD) [*Vassanadumrongdee and Matsuoka*, 2005].

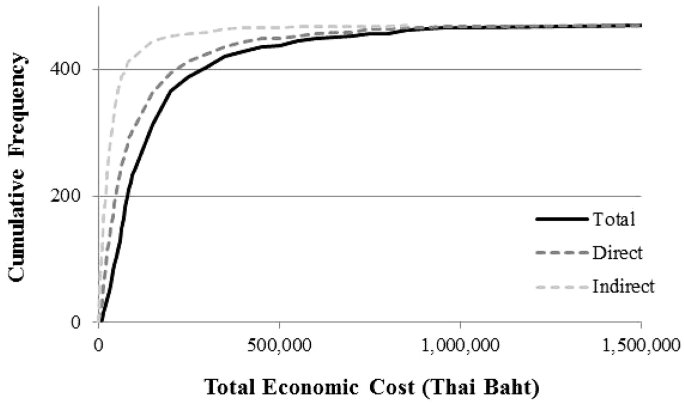

Figure 2. Frequency of total, direct, and indirect costs.

Ex post nonhealth-related losses during the flood was the second-highest cost category. Median nonhealth-related losses during the flood were about THB 25,343. Foregone income was the largest component of nonhealth-related losses incurred by households during the flood (mean of THB 27,276), followed by coping costs for alternative shelter and supplies (mean of about THB 10,160), and increased food expenses (mean of about THB 3463). About half of the households had no foregone income during the flood largely because salaried employees were able to collect their salary even when they missed work due to the flood. It is therefore the organizations that employed salaried workers that bore these losses. Only 5% of households were estimated to have foregone income over THB 100,000.

Few households experienced health-related losses. Only 52 households (11% of the sample) had at least one member who suffered from an illness or accident that the respondent attributed to the flood. In total, 62 disease episodes or accidents were reported and attributed to flood-related causes. Of these, 36 households (58%) reported incurring health costs. The majority of reported episodes were due to one of two causes: (1) *Tinea pedis*, a contagious skin infection caused by ringworm fungus, (23 cases), or (2) accidents (13 cases). In addition, rheumatism and muscular pain, common colds, and diarrhea were reported by several households, but it is difficult to know the proportion of these cases that were actually due to the flood. Two flood-related deaths were reported. One was due to electrocution and the other due to cramps that resulted in drowning. Both cases involved the death of the head of household and were in the poor neighborhoods of Bang Bua Thong in Nonthaburi. We have not adjusted our estimates of household economic losses using the value of a statistical life (VSL) in Bangkok [*Vassanadumrongdee and Matsuoka*, 2005] to include these two deaths. Had we done so, the total economic losses experienced by the households in our sample would have been much higher (roughly double).

The majority of health-related losses were borne by only a few households. Most households in which a member was ill incurred very modest health losses—median heath loss was THB 600. About 29% of households with a sick or injured member bore no health loss. However, health costs varied widely across households, from zero to THB 42,630. The magnitude of indirect health losses was much greater than direct health losses. In addition, only 12 households (representing 23% of households with a sick or injured member) incurred indirect health losses due to foregone wages (as a result of a sick or injured individual missing work or due to a caregiver missing work).

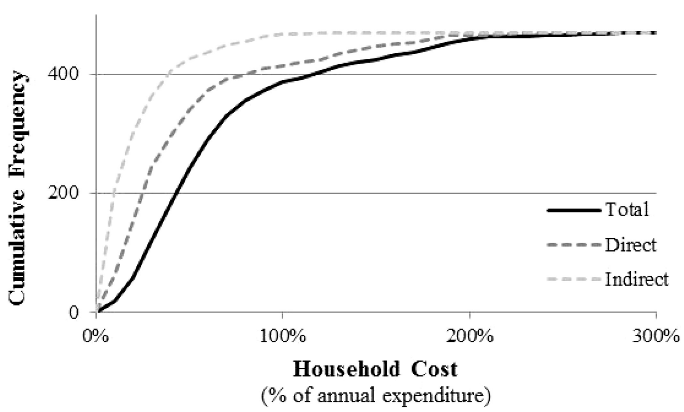

Figure 3. Frequency of total, direct, and indirect costs as a percentage of annual expenditure.

Preventative costs incurred by households before the flood amounted to a relatively small proportion of total household cost (Figure 4a). Ex ante preparation costs included supplies and labor to mitigate losses and prepare for flooding. Households parked cars in alternate locations and purchased goods to prepare for the flood such as construction

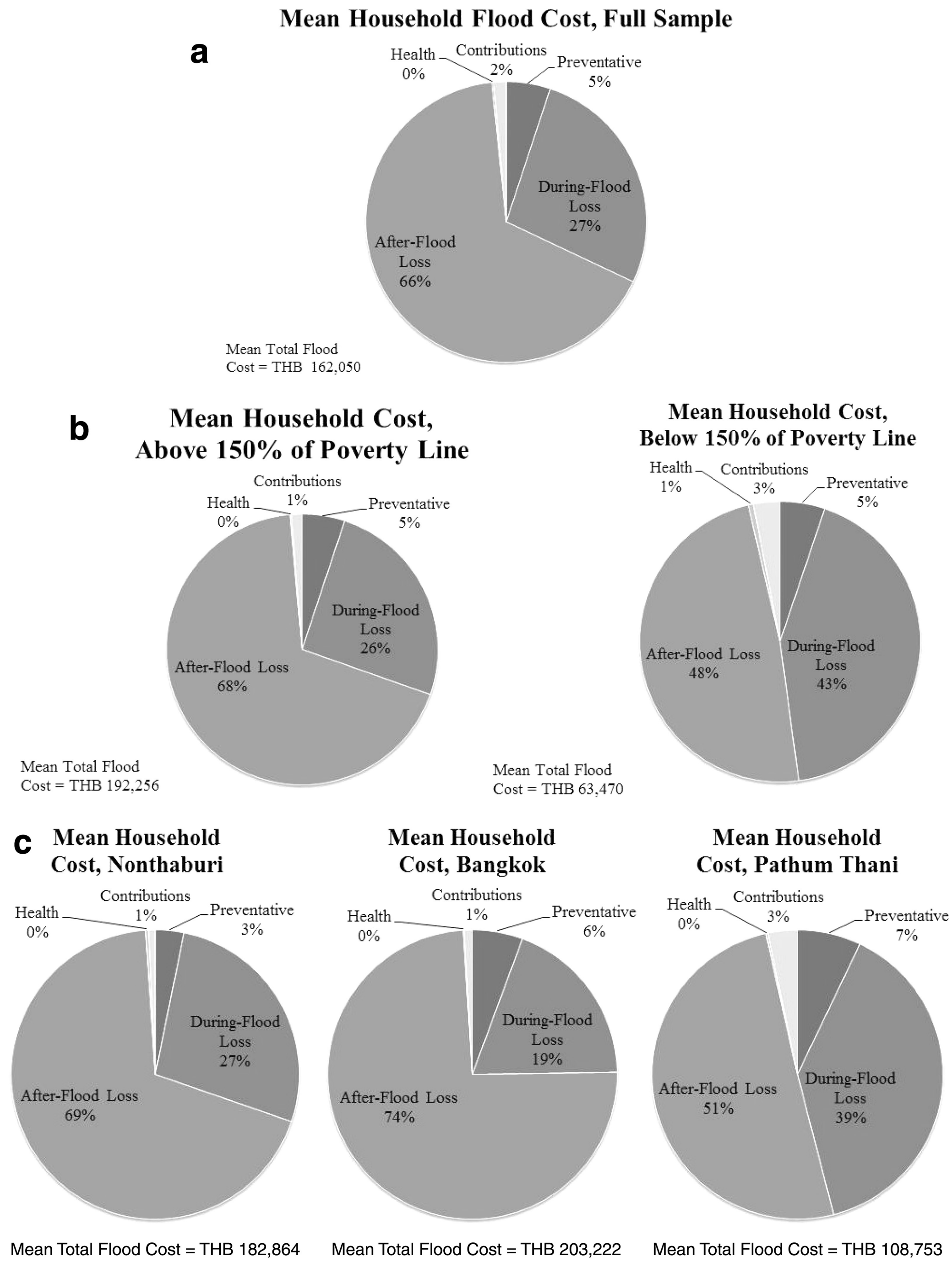

Figure 4. Composition of mean household costs. (a) Full sample. (b) By poverty category. (c) By province. Note that about 23% of the sample (110 households) had annual expenditures that were less than 150% of the poverty line..

materials, sandbags, and water pumps. Median preventative costs were about THB 3409 (USD 111). However, costs range from zero to over THB 180,770. Less than 6% of households had preventative costs in excess of THB 30,000. Indirect expenditures (own labor and volunteer labor to take preventative actions) tended to be much greater (median of THB 2500) than direct expenditures on supplies and hired labor (median of zero).

Nearly all households received disaster compensation, which was provided from various sources including the national government, employers, and aid organizations. The median value of disaster compensation received was THB 25,000 (about US$800). Few households generated additional

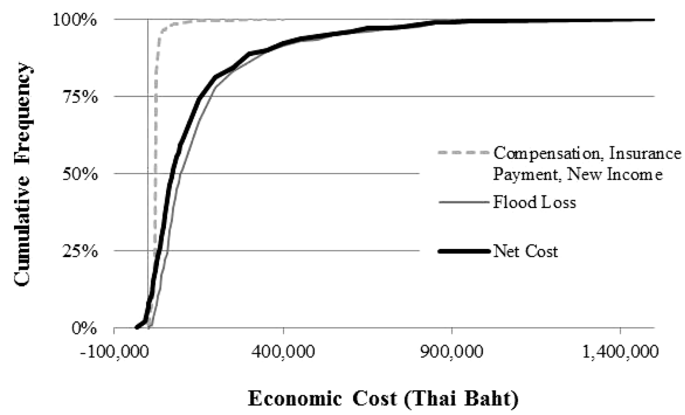

Figure 5. Cumulative frequency distributions of economic costs (net cost, flood loss, and positive payments).

income during the flood (4% of our sample). Most of these households created new income sources such as selling food and drinks or providing boat transportation. By including compensation and income from new sources, the median value of net flood losses was THB 71,789. Seven percent of the sample households had zero or negative net flood losses (i.e., some households benefited) after accounting for compensation and income from new sources. Figure 5 presents the cumulative frequency distribution total household costs, compensation received and net costs. As illustrated, compensation paid made a relatively small reduction in the total economic losses of the vast majority of households.

5.4. Distribution of Economic Costs Across Income Groups

Economic costs also varied considerably across poor and nonpoor households. Poor households were defined as having expenditures below 150% of the national poverty line. The national poverty line was expenditures of THB 1443 per person per month in 2007 *[United Nations Development Program* (*UNDP*), 2010]. Adjusting for inflation, this is equivalent to THB 1618 per person per month in 2011. Households with expenditures under THB 2427 per person per month were considered to be poor. In our sample of 469 households, 110 households (23%) were defined as poor.

Poor households incurred much lower total costs than nonpoor households, both in terms of direct and indirect costs. Median total costs for nonpoor households (THB 121,896) were more than twice as large as median total costs for poor households (THB 52,123). For both income groups, after flood losses were by far the largest category, followed by losses incurred during the flood (Figure 6). Median losses during the flood (stage 2) were comparable for the nonpoor (THB 26,761) and poor (THB 19,304) households. In addition, preventative costs were relatively low for both nonpoor and poor households (median of THB 5273 and THB 1893, respectively). The biggest difference in losses between nonpoor and poor households was for after flood (stage 3) losses (median values of THB 69,652 and THB 21,920, respectively). This large difference in ex post losses was due to wealthier households owning more property that was at risk and that was subsequently damaged.

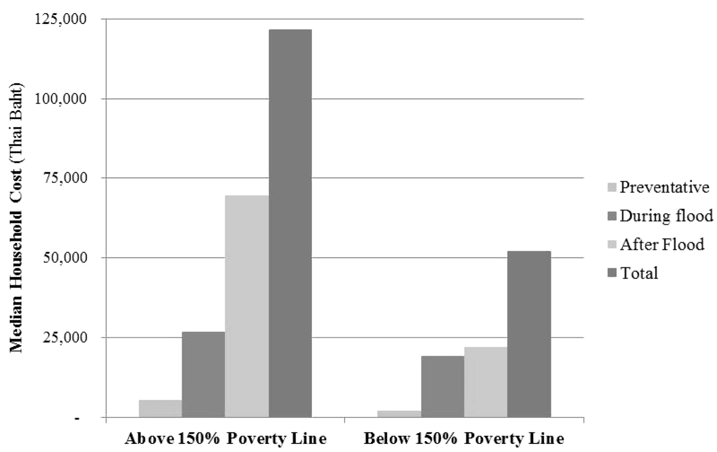

Figure 6. Median household costs, by loss type and income group.

Nonhealth losses during the flood were a much larger share of poor household total costs (43% of mean total costs) than of nonpoor households (26%) (Figure 4b). In contrast, nonpoor households had a larger share of costs accounted for by ex post loss (68%) than poor households (48%). This is due, in part, to poor households being more likely to forego wages when missing work. The ratio of preventative costs to total costs was approximately the same for nonpoor and poor

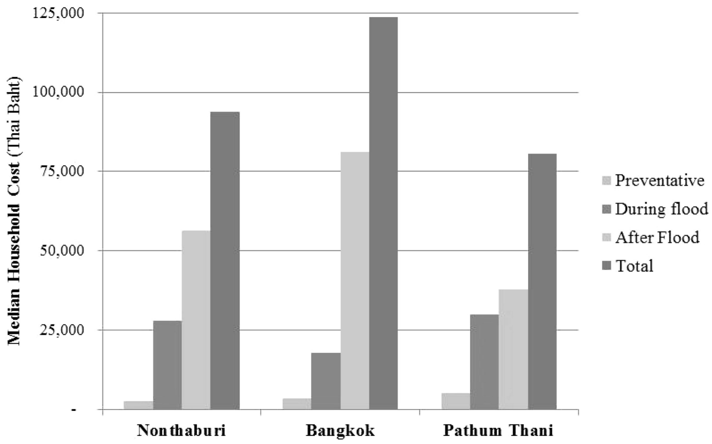

Figure 7. Median household costs, by province.

households (5%). Nonpoor households were slightly more likely to evacuate from their homes—77% of nonpoor households had at least some members evacuate compared to 65% of poor households.

In terms of after flood losses, poor households tended to have relatively greater repair and rehabilitation costs as a percentage of housing value (median of 5% of house value, for poor households), compared to nonpoor households (median of 2% of house value). About 6% of poor households (six households) had repair costs that were more than 50% of house value, compared to 3% of nonpoor households (nine households). One poor household reported repair costs that exceeded the self-reported market value of their house.

The difference between the incidence of flood-related health cases in poor and nonpoor households was not statistically significant. In addition, incidence of flood-related health cases was similar across low-income and middle-income neighborhoods. Neighborhoods are grouped into low-income and middle-income categories. Each of the three provinces has one category of low-income neighborhoods and one category of middle-income neighborhoods. So, if health cases were evenly distributed, the income category within each province would have 16% of health cases. Five of these categories (Don Mueang low-income, Nonthaburi low- and middle-income, Pathum Thani low- and middle-income) have between 16 and 21% of the cases. However, the Don Mueang middle-income neighborhoods only have 3% of the health cases. Poor and nonpoor households with at least one sick or injured member had similar total health losses (median of THB 750 and 500, respectively).

Nonpoor households had higher preventative costs (median THB 5273) than poor households (median of THB 1893) because they have more property at risk and are more able to afford such preventative measures. However, the vast majority of households in both income groups took some preventative measures. A slightly smaller percentage of poor households (90%) took preventative action than nonpoor households (94%). The proportion of poor and nonpoor households that moved belongings to higher ground or the second floor were comparable, but slightly more poor households built scaffolding structures within the house as temporary living or storage space. Poor households were more likely to resort to scaffolding because a greater proportion of poor households lived in one-story dwellings. In addition, poor households were less likely to build concrete block or sandbag flood barriers.

Poor and nonpoor households tended to bear similar burdens in terms of costs as a percentage of annual expenditure. About 14% of poor households and 19% of nonpoor households had losses that were equivalent to or greater than their annual expenditure. Households in *Bang Bua Thong* and *Don Mueang* tended to have greater losses as a percentage of annual expenditure than households in *Klong Luang* (Figure 7). In our sample, *Bang Bua Thong* and *Don Mueang* also had larger shares of poor households. About 22% of households in *Don Mueang* (Bangkok) and *Klong Luang* (Pathum Thani) were poor, compared 27% in *Bang Bua Thong* (Nonthaburi).

5.5. Results of Multivariate Analyses

The regression model (equation (1)) used to examine the factors associated with household preventative costs (i.e., before the flood) explained little of the variation in the data (adjusted $R^2 = 0.17$). Households that owned cars and had a college education spent somewhat more on preventative costs (Table 5). Whether the household received a flood warning at the district level was not statistically significant. Before the 2011 flood arrived in the greater Bangkok metropolitan area, most households in the study areas knew it was

10.1002/2014WR015982

Table 5. OLS Regression Results for Preventative Costs, Ex Post Flood Losses, and Total Costs

	Preventative Expenditure				Ex Post Flood Losses				Total Flood Costs			
	(1)		(2)		(1)		(2)		(3)		(4)	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Annual household expenditures	0.007[b]	0	0	0	0.26[c]	0.04	0.22[c]	0.05	0.26[c]	0.04	0.22[c]	0.05
Cars owned	2626[c]	770	2569[c]	801	49,830	8226	45,713[c]	8326	51,184[c]	8236	47,927[c]	8434
Education level												
High school or vocational	2106	1532	1704	1,620	−9120	16,350	−13,702	16,999	−4877	16,390	−8,347	17,056
College or more	7223[c]	1829	7244[c]	2,270	106,052[c]	19,431	46,769[b]	23,639	112,475[c]	19,559	58,195[b]	23,904
Flood warning (province specific)	1582	1732	−214	1876	−35,933[a]	18,362	−9535	19,530	−33,033[a]	18,523	−10,085	19,752
Flood depth (first floor)					143	129	209	146				
Neighborhood												
YaJai (low income)			1024	3063			15,690	33,058			27,719	32,255
FangNean (low income)			−727	2978			3299	31,039			7,394	31,358
Chollada (middle income)			−1834	3574			150,169[c]	37,147			146,512[c]	37,639
Pattaranivate (middle income)			−2471	3504			67,382[a]	36,423			62,957[a]	36,901
Ruamjairuk (low income)			2597	3230			15,008	35,232			31,602	34,020
Promsumrit (low income)			1859	2959			−841	32,287			14,176	31,160
Saraneepark (middle income)			6335[a]	3329			109,814[c]	34,794			109,661[c]	35,061
Chudapa (middle income)			−2448	5715			58,885	59,555			49,067	60,176
Suksombun (low income)			1083	2903			−1047	30,878			11,359	30,572
PhinicPark (middle income)			4277	3055			−22,283	32,059			−10,978	32,168
Phapinjad (middle income)			4229	3302			33	34,626			−812	34,773
Constant	51	1909	1068	2805	25,915	26,313	−1.470	31,819	44,879[b]	20,413	18,451	29,540
R^2	0.138		0.167		0.391		0.433		0.407		0.444	
Adj R^2	0.129		0.138		0.383		0.412		0.4		0.424	
Obs	469		469		469		469		469		469	

[a]Statistically significant at the 10% level.
[b]Statistically significant at the 5% level.
[c]Statistically significant at the 1% level.

coming, and almost everyone incurred preventative costs to mitigate the expected losses. The majority of households received provincial-level flood warnings in *Don Mueang* and *Klong Luang* and *Bang Bua Thong*. After controlling for socioeconomic factors and provincial-level flood warning, there were few neighborhood-specific effects on the magnitude of preventative costs that households incurred, with the exception of one neighborhood.

Table 5 also presents the results of the regression models (equations (2) and (3)) that examined factors associated with variation in the ex post household losses (i.e., during and after the flood) and total flood costs. These models explain more of the variation in ex post household losses (adjusted $R^2 = 0.43$) and total costs (adjusted $R^2 = 0.44$). Since ex post household losses tend to comprise the majority of total costs, the results of both models are similar. Three groups of variables stand out as associated with ex post household losses and total household costs. First, households with higher annual expenditures and more cars incurred more losses because they had more property at risk. Households with a college education or higher also suffered higher losses, which we interpret as an additional indicator for more property at risk.

Second, even after controlling for socioeconomic factors, neighborhood effects were large and statistically significant. Specifically, household losses in middle-income neighborhoods *Bang Bua Thong* and *Don Mueang* were higher than in Klong *Luang*. This is expected because the floodwaters were deeper in *Bang Bua Thong* and arrived with much less advanced warning than in *Klong Luang*.

Third, provincial-level flood warnings were not significant in any of the ex post loss model specifications that controlled for neighborhood effects. Such warnings may have been less useful during the 2011 greater Bangkok flood than in flood events that unfold more quickly. The amount of time households had to prepare before the arrival of the flood appears to be an important factor for flood loss mitigation. Longer lead times are usually associated with lower damages and lower death rates [*Parker et al.*, 2009]. During slow moving flood events, such as the 2011 Thailand flood, more people are informed in advance about the event. By the time floodwaters reached greater Bangkok, most households were aware the flood was coming, but these warnings might not have conveyed sufficient information about appropriate mitigation actions or the depth of floodwater that households could expect.

6. Discussion

The estimates of household economic losses presented in this paper are valuable as one of many inputs needed to undertake an integrated water resources assessment of flood control strategies for Bangkok. The estimates themselves are not sufficient grounds on which to base policy recommendations. However, our results do suggest some policy alternatives should be the focus of more serious analysis.

First, from the household's perspective, the top priority of the State should be to save lives. This is true not only on moral grounds, but on economic grounds as well. Two people in our sample households lost their lives in the flood. If we had assigned a monetary value to these two deaths using an estimate of the value of a statistical life estimated for Bangkok, the economic value of this mortality loss would be more than the estimated total household costs for the entire sample of 469 households. Saving more lives would also appear to be relatively straightforward and cheap (cutting off electricity to flooded areas more quickly). This finding also suggests that it might be useful to design an insurance product that offered protection against both against loss of life and property losses.

Second, also from a flood insurance perspective, there would appear to be a greater need for catastrophic insurance than for insurance against the smaller losses experienced by most households in our sample. Our results show that many households even in the most severely flooded parts of Bangkok suffered what are best described as moderate, but not catastrophic losses. Based on these results, catastrophic insurance should be relatively cheap because even in such a severe event as the 2011 flood, few people suffered catastrophic losses. Insurance providers that offer households products to insure against such catastrophic losses would have to carefully protect themselves against the moral hazard that households would not take sufficient care ex ante to minimize losses if they had catastrophic insurance. However, this is a well-understood problem for the insurance industry, and copayments and coverage caps should provide adequate protection.

The findings also bring into sharper focus other important policy questions that we cannot yet answer based solely on the estimates of household economic losses. For example, if the policy focus is on protecting residential areas, should the Government of Thailand put more emphasis on structural or nonstructural flood control strategies? Conventional wisdom holds that flood-warning systems are among the most cost-effective nonstructural options to reduce flood losses. Having more time to react to the evolving flood situation probably would have helped some households reduce their economic losses, but receiving the information contained in a provincial-level flood warning did not seem to matter much to the households in our sample. Although almost everyone in Bangkok knew the flood was coming, it was challenging for people to assess the conflicting information coming from different sources and to determine what the likely consequences of the flood would be for them. Despite the massive news coverage, many people in the neighborhoods we studied were still caught off guard by the severity of the flood in their own neighborhood. This was partially due to the content of the information obtained from the media, which often was not of much practical value. For example, instead of being informed about the volume of water coming, households could have benefited more from information about expected water depth, which would have enabled households to better decide whether to move cars and belongings. With better information about the depth of floodwaters to be expected, households might not have placed as much emphasis on building barriers to prevent water from coming into the house. Households could have devoted more effort to moving their belongings to higher ground.

Almost all the households in our study took preventative actions to mitigate flood losses—such as moving possessions higher—to a second story, roof, or higher ground (86%), moving vehicles (46%), and sandbagging (35%). Many of these preventative actions proved to be ineffective, and it is unclear how much households knew about the likely effectiveness of various loss prevention measures. For the few households that did not take preventative measures, some did not take action either because they did not believe their houses would be affected, or they wanted to wait and see the progression of the flood. Some people who took preventative actions did not receive explicit flood warnings at the province level. They acted based on

10.1002/2014WR015982

Table 6. Mean Household Damages, Comparison of Study Results to World Bank (2012) Estimates

	Housing Damage	Household Goods Damage	Temporary Shelter	Prevention	Other During + Post Flood Damages	Health Care Costs	Household Contributions to Community	Total (THB)	Total (USD)
World Bank Estimates									
Bangkok	2565	19,486	17,276	N/A	N/A	N/A	N/A	40,336	1310
Nonthaburi	3240	19,686	19,455	N/A	N/A	N/A	N/A	43,399	1409
Pathum Thani	4701	19,448	22,023	N/A	N/A	N/A	N/A	47,179	1532
Study Estimates									
Bangkok (*Don Mueang* District)	136,387		3770	11,441	35,089	199	1832	203,222	6598
Nonthaburi (*Bang Bua Thong* District)	99,704		3780	5861	45,766	584	1383	182,864	5937
Pathum Thani (*Klong Luang* District)	41,342		731	7707	41,574	250	3568	108,753	3531

the news coverage and common knowledge that the flood was progressing toward greater Bangkok. But even for those who did receive province-level warnings, this information did not make much difference because it turned out that there was not much they could do to reduce property losses, with the exception of those who moved their cars out of the area and moved their possession to higher grounds.

Even though members of many households evacuated their homes, our findings show that many people did not do so immediately after the floodwaters arrived. Thus, these members were at risk of electrocution and other flood-related accidents and diseases. Even after people evacuated, many returned often to their homes before the floodwaters receded to check on their belongings. Short animations broadcast on television tended to fill information gaps left by government sources. These animated service announcements provided instruction on how to keep safe, to lower health risk, and how to cope with flood waters if people did not want to evacuate.

For residents in our study areas who survived, the 2011 flood was a traumatic event, one that people will remember all their lives. But for the vast majority of these households, the economic losses they incurred should not be characterized as "catastrophic." Our findings from three of the most severely affected neighborhoods of greater Bangkok show that median household economic losses were about THB 95,138 (US$3089). Economic costs were higher for middle-income households than for poor households because they had more property at risk, and somewhat higher for residents in *Bang Bua Thong* where people had little warning before the floodwaters rose rapidly in their neighborhood and were especially deep. However, economic costs as a percentage of annual household expenditures were similar between poor and nonpoor households (53% and 48%, respectively).

The median household economic cost was equal to about 6 months of self-reported household expenditures (and about 3 months of self-reported household income), a large loss to be sure, but probably not a life-changing economic event. For most households, recovery efforts began quickly. Households had to pay for cleaning their homes and making minor repairs, but most homes were constructed of concrete or simple wood frames, neither of which suffered permanent structural damage. Repair and rehabilitation costs to houses were about 2% of the self-reported market value of the house. Very few households experienced morbidity losses, and for those that did, the economic value of the losses was very low (less than 1% of median household economic costs).

Our findings of household economic losses are approximately 2–5 times higher than the estimates of the *World Bank* [2012], depending on the province (Table 6). This is largely due to two reasons. First, our estimates included cost components that were not included in the World Bank study. The World Bank conducted a rapid assessment of all sectors that did not make use of household surveys. The World Bank team estimated housing damage based on the number of dwellings that were likely inundated, based on flood maps. To estimate cost of damage to buildings, representative costs were determined by type of housing (based on construction materials, number of floors). On the other hand, our estimates included both direct and indirect costs before, during, and after the flood. We also captured more recovery costs by conducting the second-round, follow-up survey 1 year after the floodwater receded. Second, our study focused on households in three of the most severely affected areas of the Greater Bangkok Metropolitan area where losses were clearly higher.

Our analysis of the composition of the total household economic costs revealed that about 5% of the total household economic costs were incurred before the flood, 27% during the flood, and 66% after the flood. This does not necessarily mean that preventative expenditures were too low; indeed, as noted, many of the preventative expenditures undertaken seem to have been ineffective. But it does point to the need for government policy to focus on the importance of evaluating alternative policies to reduce households' ex post economic costs. Very few households in our sample had any kind of flood insurance. Despite the difficulty of assessing risks of future flooding and the moral hazards of encouraging development in flood-prone areas, there would seem to be an important role for government to facilitate the development a market for catastrophic flood insurance for households.

Finally, this paper demonstrates that it is practical and feasible to collect microeconomic data from households affected by floods using in-person interviews. Such microlevel data yield a much clearer and comprehensive picture of household floods costs.

Acknowledgments
Financial support from the Thailand Research Foundation, the Economy and Environment Programme for Southeast Asia, and a National Science Foundation Graduate Research Fellowship (grant DGE-1144081) are gratefully acknowledged. We thank Hermina Francisco and Wiktor Adamowicz for helpful comments and suggestions on an earlier draft. The data sets upon which the analyses in this paper were based are available upon request from Orapan Nabangchang (orapann@gmail.com).

References

A.M. Best (2012), *Flood Losses Prompt Key Changes in Thai Insurance Industry, Best's Briefing: Global Insurance*, Oldwick, N. J.

AON (2012), 2011 Thailand floods event recap report, Chicago, Ill, March 2012.

Asian Correspondent (2011a), *Thailand: Why Was so Much Water Kept in the Dams?—Part II*, Bristol, U. K. [Available at AsianCorrespondent.com.]

Asian Correspondent (2011b), *Bhumipol Dam: Water Entering the Dam, Discharge of Water, and Capacity*, Bristol, U. K. [Available at AsianCorrespondent.com]

Asian Development Bank (ADB) (2012), *Flood Management for Chao Phraya River Basin: Direction and Approach*, Bangkok, Thailand.

Dutta, D., S. Herath, and K. Musiake (2003), A mathematical model for flood loss estimation, *J. Hydrol.*, *277*, 24–49.

EM-DAT (2011), The OFDA/CRED International Disaster Database, www.emdat.be, Univ. catholique de Louvain, Brussels.

Grothmann, T., and F. Reusswig (2006), People at risk of flooding: Why some residents take precautionary action while others do not, *Nat. Hazards*, *38*(1–2), 101–120.

Hanemann, W. M. (1992), Preface: Notes on the history of environmental valuation in the USA, in *Pricing the Environment: The European Experience*, edited by S. Navrud, pp. 9–14, Oxford Univ. Press, Oxford, U. K.

Krutilla, J. V. (1966), An economic approach to coping with flood damage, *Water Resour. Res.*, *2*(2), 183–190.

Merz, B., and A. H. Thieken (2004), Flood risk analysis: Concepts and challenges, *Oesterr. Wasserwirt. Abfallwirt.*, *56*(3–4), 27–34.

Orie, M., and W. R. Stahel (2013), Case study 3. The 2011 Thai floods, in *The Geneva Reports: Risk and Insurance Research. Insurers' Contributions to Disaster Reduction—A Series of Case Studies*, edited by M. Orie and W. R. Stahel, 30 pp., Geneva Assoc., Geneva, Switzerland.

Panya Consultants (2009), *Climate Change Impact and Adaptation Study for Bangkok Metropolitan Region*, Bangkok, Thailand. [Available at www.scribd.com/doc/71955161/31/Flood-in-the-Lower-Chao-Phraya-River-Basin.]

Parker, D. J., S. J. Priest, and S. M. Tapsell (2009), Understanding and enhancing the public's behavioral response to flood warning information, *Meteorol. Appl.*, *16*, 103–114.

Pattanayak, S., J. C. Yang, B. Kumar, and D. Whittington (2005), Coping with unreliable public water supplies: Averting expenditures by households in Kathmandu, Nepal, *Water Resour. Res.*, *41*, W02012, doi:10.1029/2003WR002443.

Poulos, C., et al. (2011), Costs of illness due to typhoid fever in five Asian countries, *Trop. Medicine Int. Health*, *16*(3), 314–323.

Smith, K., and R. Ward (1998), *Floods: Physical Processes and Human Impact*, John Wiley, Hoboken, N. J.

Smith, V. K. (2004), Fifty years of contingent valuation, in *The International Yearbook of Environmental and Resource Economics 2004/2005: A Survey of Current Issues*, edited by H. Folmer and T. Tietenberg, pp. 1–60, Elgar, Cheltenham, U. K.

Thieken, A. H., M. Muller, H. Kreibich, and B. Merz (2005), Flood damage and influencing factors: New insights from the August 2002 flood in Germany, *Water Resour. Res.*, *41*, W12430, doi:10.1029/2005WR004177.

United Nations Development Program (UNDP) (2010), Thailand human development report 2009: Human security, today and tomorrow, report, Bangkok.

Vassanadumrongdee, S., and S. Matsuoka (2005), Risk perceptions and value of a statistical life for air pollution and traffic accidents: Evidence from Bangkok, Thailand, *J. Risk Uncertainty*, *30*(3), 261–287.

White, G. F., R. W. Kates, and I. Burton (2001), Knowing better and losing even more: The use of knowledge in hazards management, *Environ. Hazards*, *3*(3–4), 81–92.

World Bank (2012), *Thai Flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning*, Bangkok, Thailand.

Yusuf, A., and H. Francisco (2010), *Hotspots: Mapping Climate Change Vulnerability in Southeast Asia*, Econ. and Environ. Program for Southeast Asia, Singapore.