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Adoption of flood preparedness actions: A household level study in rural communities in Tabasco, Mexico

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ABSTRACT

Of all the natural disasters, floods are the most common. While they affect most countries around the world, poor communities are particularly vulnerable to flood risk. The use of early preparedness measures is key for minimizing related flood impacts; however, little is known about what drives their adoption by households in those communities. We undertake a household survey of individual flood preparedness decisions in ten communities in the Mexican state of Tabasco, which are exposed to frequent flooding and also highly vulnerable from a socio-economic perspective. Statistical analysis reveals that in these communities having accessible flood risk maps, sharing flood experiences with family, having early warning systems, and having shelters, amongst other factors, all increase the likelihood of household preparedness actions. This information is important as it can be used to assist in diagnosing the existing capacities and gaps in managing flood risk in these communities. For example, while having knowledge of the risk map is found to significantly increase the likelihood of protecting the belongings, only 8% of the survey respondents were aware of their community's risk map.

1. Introduction

Physical damage from natural disasters has increased substantially over the last decades, with floods accounting for 47% of all weather-related disasters from 1995 to 2015, affecting 2.3 billion people and killing 157,000 [44]. Eighty percent of the total population affected by riverine flooding each year are relegated to 15 least developed or developing countries in Africa, Asia, and Latin America [50]. In an aftermath of a disaster, low-income families that are already struggling can be pushed into destitution because they have fewer assets, less diversified income sources and, as it is often the case in low income countries, lack adequate financial protection [46]. However, investing in disaster preparedness prior to a flood event can help mitigate the negative impacts of the flood catastrophe occurrence and, when selected well, be cost effective over time (that is the reduction in expected losses is higher than the cost of implementing these measures) [21,28,32,49].

In regard to floods, there has been a significant focus on integrated flood risk management in recent years, aimed at minimizing adverse effects and at learning to cope with these events [25,40,47]. Integrated flood risk management involves managing flood risks at the scale of river basins, and it requires both structural approaches (e.g. a levee or barrier) and non-structural ones (e.g. improving risk awareness, emergency alerts) to managing flood risk instead of traditional approaches that focus only on structural improvements such as dikes and levees [45]. One of the key aspects of integrated flood risk management is the use of loss reduction and preparedness measures prior to a flood event such as through flood-resilient design and construction, development of early warning systems, insurance, awareness campaigns including trainings and education related to disaster preparedness [34,47]. However, there is a significant gap in the literature in understanding what drives these flood preparedness actions at the household level in poorer communities situated in least developed or developing countries. Bubeck et al. [4] conducted a literature review of sixteen studies

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that examined factors of influence on household flood preparedness behavior; *all* of these studies were conducted in high income countries, namely the U.S., Europe and Japan. Furthermore, these studies have mostly focused on the purchase of flood insurance as the key household's preparedness measure. But for poorer communities' flood insurance is often not available, or when it is, not affordable. Significant numbers of households in poorer communities are at risk of flooding and struggle to cope in an aftermath of a disaster [15]. Thus, better understanding what drives the adoption of preparedness measures that would be more feasible for households in low-income areas is important.

By utilizing data collected from a face-to-face survey, this paper focuses on determining the drivers of three key flood preparedness actions taken by households in ten poor communities in Tabasco, Mexico. Specifically, we analyze whether a household a) takes measures to protect their belongings; b) identifies a safe-meeting point in case of a flood-related emergency affecting their family; or c) participates in emergency preparedness activities, such as disaster drills. These variables were chosen because if widely adopted by households, these actions were found to make a substantial difference in reducing losses when severe flooding occurred [29]. These stated actions from our survey, compared to flood-preparedness actions taken in high-income countries such as having insurance or expensive structural flood-proofing measures [4], highlight that several relatively low-cost options are available to households in poor communities to prepare for the frequent floods they face. Importantly, our statistical analysis allows for insights into the various factors that lead to the adoption of these key preparedness actions at household level. And we find some evidence that community actions encourage household actions as well.

The novelty of our work lies in our utilizing face to face survey data to perform an analysis on the adoption of three key flood preparedness actions taken by households in an area of the developing world where a significant gap of this knowledge exists, Tabasco, Mexico. We analyze not only the degree of adoption of these actions, but more importantly the drivers that lead to their adoption which have not been well understood in general in a developing country context. Also, our study measures whether community level actions make the individual households proactive in taking disaster preparedness action which is important from a management perspective. Moreover, this understanding is critical for the potential to begin the process of implementing an integrated flood risk management approach that uses loss reduction and preparedness actions prior to a flood event. This is key in our Tabasco study area given the persistent flooding here combined with the low levels of community financial resources available to deal with the annual flood hazard as we describe next.

The remainder of the paper is structured as follows. Section 2 discusses the literature on flood hazard preparedness with a focus on existing research in a developing country context. Section 3 provides an overview of the flood exposure in our study area of Tabasco, Mexico. Section 4 discusses the data, hypotheses and the methods employed. Section 5 presents the results of the multiple regression analysis. Section 6 concludes with a discussion.

2. Management of flood risk through flood hazard preparedness

Integrated flood risk management strategies should consider a range of structural and non-structural measures to prevent floods or to reduce their consequences [17]. Structural prevention measures often involve the construction of a structure designed to be defensive in the event of a flood [16] such as dams and dikes; non-structural measures often focus on human actions [16,3]. Dams, dikes, drains, and diversions are often viable risk reduction strategies against flooding. While they offer some level of protection, they do not ensure complete protection against catastrophic floods [17,9]. Furthermore, some of these interventions might only redistribute risks (for example prevention of floods upstream can cause floods to occur downstream) than reducing them overall [26,27,31]. Additionally, due to a lack of funds to employ structural measures, low-income countries often invest less in structural flood protection [39]; this implies that flood risk management there mostly relies on limiting the consequences of floods via preparedness actions at the household level.

While not as extensive as the literature on flood preparedness from a developed country perspective, a number of studies have analyzed flood preparedness in developing country contexts. Mishra and Suar [29] constructed a 20-item flood preparedness scale relying on several flood preparedness brochures and webpages to study flood preparedness behavior in Orissa, India. They included questions such as "Do you keep the following things (candles, flash lights, serviceable radio etc.) ready for the flood season?"; "Do you know any shelter house nearby" among many other actions. They find that disaster experience and formal education were often positively correlated with these flood preparedness actions. In a separate study Mishra and Suar [30] also find that disaster-related education such as knowing what to do after getting flood warnings partially mediates the adverse impact of anxiety on flood preparedness. Likewise, Said et al. [37] find that in rural Punjab India flood experience also influences household preparedness actions in poorer communities.

Other studies have analyzed preparedness actions from the perspective of these actions being key parameters of both resilience and coping strategies in communities vulnerable to climate related disasters. Joerin et al. [22], compare two communities in Chennai, India to understand the resilience of those communities to climate-related disasters such as cyclones and riverine floods. One of the resilience parameters they study is the measure of whether the household has an emergency supply kit. Results from their household surveys indicate that while households with disaster experience (damaged house) are more actively involved in community based organizations, they are significantly less prepared to face such disasters as fewer households possess sufficient basic emergency equipment (medical kit, flash light etc.). Hilvano et al. [18] utilize capital assets of the households residing in Manicani Island, Philippines and their coping strategies as determinants of household resiliency. The coping strategy that they examine is the safekeeping of household assets/personal belongings. They find that the educational attainment of the household head has an influence on safekeeping of household assets/ personal belongings. Although specific to earthquake and not flood, Muttarak and Pothisiri [33] investigate six disaster preparatory actions (keep close watch of the situation, preparation of survival kits, planning an evacuation procedure, making an emergency plan with household members, inspection of house structure, and other preparations) for their study conducted in Andaman coast in Phang Nga province after the Indian Ocean Earthquake in 2012. They find that disaster preparedness is most effective for individuals with high educational attainments and concluded that formal education can increase disaster preparedness and reduce vulnerability to natural disasters.

The above studies have consistently found disaster experience and educational attainment as key predictors of household disaster preparedness in a developing country context. Additionally, numerous studies have emphasized the importance of early warning systems (or "EWS") in connection to international efforts to reduce the risk associated with disasters [23,8]. Using a survey of 640 households affected by 2010 flood in Punjab, Pakistan, Turner et al. [43] estimated the

effect of early warnings on the likelihood of households taking actions to mitigate damages. They find that the more known face-to-face flood warnings (neighbors, mosque announcements, government official) are more effective than other less known information sources (television, radio) in prompting mitigation actions.

Relatedly on the importance of the known local context for prompting mitigation, Thurairajah et al. [42] assert that many nations carry out actions that are related to reducing disaster risk, but that the success of these actions is hampered by the lack of incorporation of the local conditions and vulnerabilities. This indicates the need to include local knowledge and skills from specific communities in disaster prevention activities. Interestingly too, Hoffmann and Muttarak [19] find that the effect of education on disaster preparedness is mediated through social networks and disaster risk perception in Thailand.

While for our study we focus on determining the drivers of three key flood preparedness actions taken by households in ten poor communities in Tabasco, Mexico, learnings from a developed country context are also relevant and we highlight a few here. Poussin et al. [36] conducted a household survey in France and classified the preparedness measures undertaken by the households under three categories: structural measures (measures related to level of ground, foundation strength etc.), avoidance measures (moving the heater in the upper floor, furniture placed and chosen to avoid flood loss, personal and important documents placed in upper floor etc.) and emergency preparedness measures (a family emergency plan in place, power generator kept at home etc.). In our analysis, we include the avoidance measures (such as protect the belonging) and emergency preparedness measures which are more appropriate in the context of poor communities. In regard to non-structural measures such as moving the heater in the upper floor, a number of variables in Poussin et al. [36] are found to be influential in households' preparedness decisions such as flood experience, education level, age, incentives from insurers and local social networks. However, Grothmann and Reusswig [14] find that reliance on public flood protection correlated negatively with households flood damage prevention. Other studies in the developed country context have also found that, in general, homeowners who have been flooded recently are more aware of the flood risk and are likely to take preparedness actions [14,6]. Other important explanatory variables include information about local flood risk or attending information meetings which can drive household-level adaptation [24]. Finally, a significant predictor of the ability to invest in preparedness as well as post disaster recovery is socio-economic status [41]. For example, poor people are less likely to prepare for disasters or buy insurance, but they have proportionally higher material losses and face more obstacles during the phases of response, recovery and reconstruction [10].

3. Tabasco flood exposure & study area

3.1. Flooding in Tabasco, Mexico

Tabasco is a Mexican State situated in the South-Eastern part on the Isthmus of Tehuantepec (Fig. 1, upper right) with a 184-km long coastline along the Gulf of Mexico in the North. The State is bounded by Campeche in the East, Veracruz in the West and Chiapas in the South. The topography is generally flat and low and is largely covered with lakes, lagoons and wetlands [7]. Grijalva and Usumacinta rivers are two of the largest rivers of Mexico that originate in Chiapas and is the biggest watershed of North America and by far the largest in Mexico with a catchment area of 32,259 square miles. The rivers altogether make up for 30% of all the fresh water flows of the country [12].

Floods in Tabasco are recurrent, occurring on almost a yearly basis, and flood preparation and response have long been part of the livelihoods and lifestyles of the region's residents. However, ordinary seasonal flooding has been compounded by cases of extreme flooding, such as between 2006 and 2010 when six extreme flood periods marked by continuous intense rainfall for several days occurred [12]. In particular, extreme floods in 2007 were the most severe in about 50 years. Flooding affected about 70% of the state. Over one million people were adversely affected (60% of the total population of the state of Tabasco), [38] with 158,000 requiring temporary shelter. The flood caused USD 2.55 billion in total damages ($350 million was insured) to personal and private property, agricultural crops and infrastructure, [1] and cut off thousands of people in rural areas from essential services.

For rural riverside communities, the 2007 floods marked the coalescence of a number of significant changes that have been accumulating over time. Precipitation frequency increased between 1970 and 2011 [2]. Changes in land use, especially deforestation, have contributed to increased runoff, soil erosion [1], and higher water levels. Residents are accustomed to impacts from seasonal rains and floods, such as living with half to one meter height of water for one to two months per year, but not to the new, longer-lasting, floods. Seasonal floods have now increased to one meter or higher, lasting five to six months of the year [20]. Most significantly, this severe flooding impacts livelihoods, harvest opportunities, schooling, and other aspects of every-day life. It is, therefore, important to design integrated flood risk management policies to help people in Tabasco better prepare for these more frequent severe flood impacts, for which an improved understanding of past flood preparedness decisions can provide useful insights.

3.2. Study area

In 2015 we conducted face to face surveys in ten communities in Tabasco (Fig. 1 bottom panel) which provides the household level data for our study. These ten communities are: 15 de Mayo; Constitución 1917; El Güiral; El Piñal; La Esperanza; Poblado Chanero; Pueblo Nuevo; Torno Largo 2nd Sección; Torno Largo 4th Sección; and Venustiano Carranza. The communities are located along or near the San Antonio and Usumacinta Rivers as depicted. The Usumacinta river system again is one of the world's largest in terms of volume and several branches of the river system unite in Tabasco [11]. A total of 728 households are located in these communities. The survey was conducted as a part of a larger effort our research team is associated with, aimed at measuring and improving flood resilience for communities at risk from flood across the globe.[1]

For each of these ten communities in addition to the survey data, we gathered other relevant available data from the Mexican National Institute of Statistics and Geography (INEGI; http://www.inegi.org.mx) in order to account for the overall vulnerability of these communities in terms of flood hazard, flood exposure, and socio-demographic characteristics. Specific data (Table 1) include community elevation (above sea level) in meters; distance between community center point and the nearest river (Usumacinta or San Antonio) in meters; and INEGI census section-level data for the percentage of the population employed, percentage of the population over 15 years old that did not finish primary school education, percentage of households with a vehicle, percentage

[1] We selected these communities because they all take part of the multinational community flood resilience effort in partnership with Zurich Insurance, The International Federal of the Red Cross and the NGO Practical Action. Our research group is also part of this Alliance along with IIASA in Austria. More information can be found at: http://opim.wharton.upenn.edu/risk/library/zurichfloodresiliencealliance_ResilienceWhitePaper_2014.pdf.

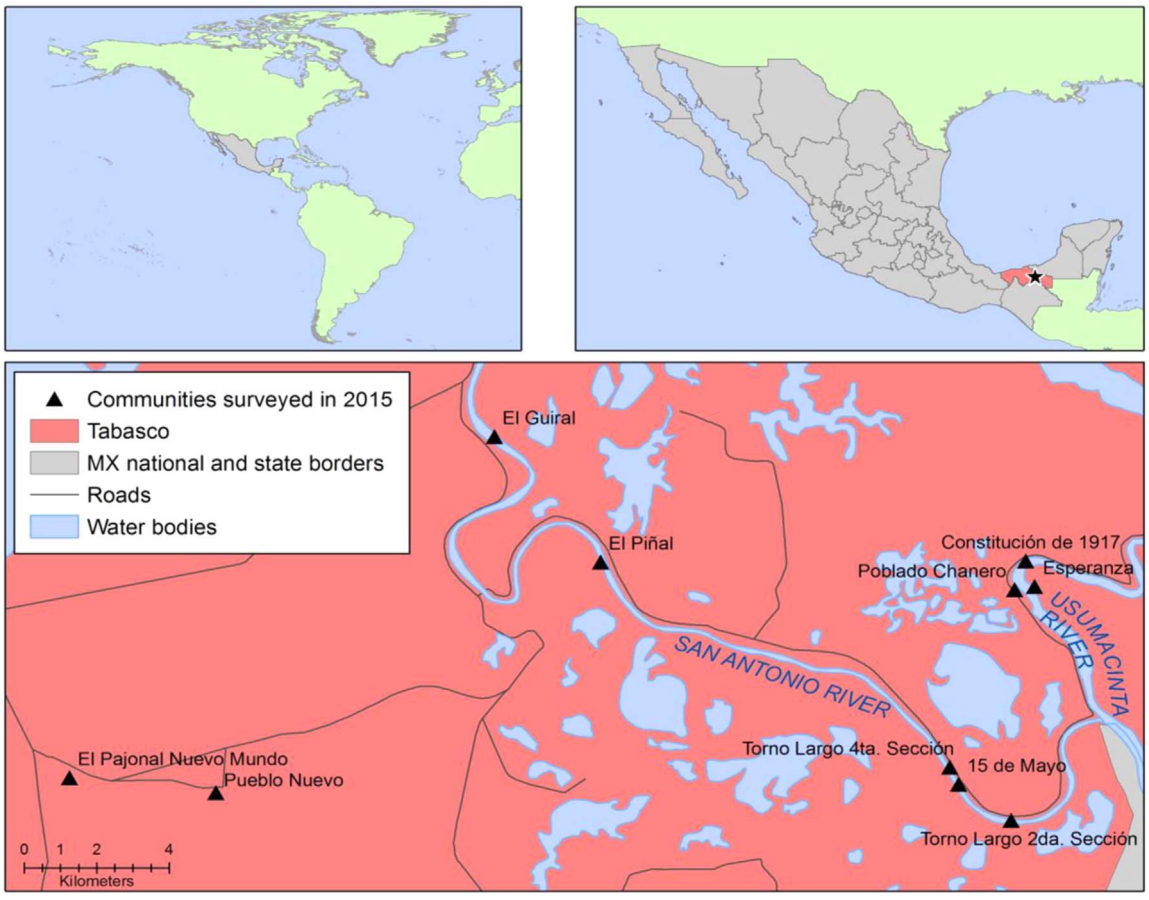


Fig. 1. Ten Communities in Tabasco, Mexico selected for the surveys.

Table 1
Summary of the Community-level data and Census data for the Ten Communities included in the analysis.

	Community-level data		INEGI census section-level data				
Community	**distance to nearest water body (meters)**	**Elev-ation (m)**	**% emp-loyed**	**% 15 yrs+ did not finish primary school**	**% vehicle**	**% radio**	**% fridge**
15 de Mayo	0.0	6.0	31.8	19.5	5.7	66.2	75.6
Constitucion de 1917	0.0	5.8	27.9	29.5	3.9	61.1	56.5
El Guiiral	0.0	5.1	31.3	24.1	1.4	54.4	68.1
El Pinal	0.9	2.0	31.7	20.3	7.7	62.4	77.6
La Esperanza	45.1	5.0	27.9	29.5	3.9	61.1	56.5
Poblado Chanero	123.2	6.2	27.9	29.5	3.9	61.1	56.5
Pueblo Nuevo	3195.1	4.7	26.8	13.9	4.6	59.8	66.7
Torno Largo 2da. Seccion	0.0	5.8	31.8	19.5	5.7	66.2	75.6
Torno Largo 4ta. Seccion	0.7	5.5	31.8	19.5	5.7	66.2	75.6
El Pajanol Neuvo Mundo	3767.6	3.8	28.5	18.1	6.0	55.3	58.2
Average for ten communities	713.3	5.0	29.8	22.3	4.9	61.4	66.7
Tabasco averages			34.6	16.3	24.5	64.4	79.8
Mexico averages			37.4	14.9	42.6	76.4	79.1

of households with a radio and percentage of households with a refrigerator.

From Table 1 we see that on average all ten communities are in close proximity to a flood risk and relatively low-lying. El Pinal in particular is at the highest risk of the 10 communities, being 0.9 m from the river at only 2 m elevation. While the average distance to

Table 2
Summary statistics of key variables included in the analysis.

Variable	Description	Mean	Std. Dev.	Expected sign
Dependent Variables				
Protect belongings	After the last flood, has your family taken measures on improving what to do in case of flooding? If yes what were the agreements? (coded 1 if yes, and agreement was actions to protect belongings)	0.46	0.49	
Safe meeting point	Does your family know or have a safe meeting point? (coded 1 if yes)	0.23	0.41	
Emergency preparedness	Does your family have emergency plan? Has your family participated in first aid training, disaster drill, and/or training for disaster prevention? (coded 1 if yes to any of these items)	0.13	0.28	
Key Independent Variables				
Knowing the risk map	Do you know the risk maps in your community? (coded 1 if yes)	0.077	0.266	+
Sharing of experience	In your family, do grandparents, parents, children or grandchildren share the experiences and lessons learned from the floods? (coded 1 if yes)	0.721	0.449	+
Emergency plan available	Does the community have a community emergency plan that accounts for floods?	0.01	0.13	+/-
Emergency team meet civil protection	Does the community emergency team frequently meet the civil protection?	0.03	0.19	+/-
Early warning available	Has an early warning system (such as siren, whistles, bells, speakers, buzzers, etc.) been realized for the betterment of the community? (coded 1 if yes)	0.018	0.133	+
Shelter available	Do you have a shelter available in case of flooding? (coded 1 if yes)	0.151	0.358	+
Services and programs to help after floods	Does this community offer services and programs to help people after the flood? (coded 1 if yes)	0.179	0.384	–
Protective actions at the household level	Have actions been undertaken by the community at the household level, such as raised floors, palafitos, tapescos, or tapancos to protect against the risk of flooding? (coded 1 if yes)	0.753	0.432	–
Protective actions at the community level	Have actions been undertaken by the community to protect against the risk of flooding at the community level, such as making embankments, constructing barrier walls?	0.586	0.493	–
Severely affected by flood	In the last 10 years, has your family been severely affected by flooding? (coded 1 if yes)	0.922	0.269	+
Working Family members	How many family members work?	2.26	0.82	+
MXN pesos lost > 5K	How much was lost during the worst flooding? (coded as 0 if less than or equal to 5000 Mexican pesos and 1 if more than 5000 Mexican pesos)	0.342	0.475	+

nearest water body for all the communities is 713 m, more than 70% of the households in our sample is within 50 m of a water body.[2] In comparison to the rest of the state of Tabasco as well as the whole of Mexico, these communities have a lower percentage of employed households, and less households with a vehicle, radio, and refrigerator. They also have less education with on average approximately 22% of total households not finishing primary school as compared to 16% and 14% in Tabasco and Mexico respectively (Table 1).

4. Survey data, methods and hypotheses

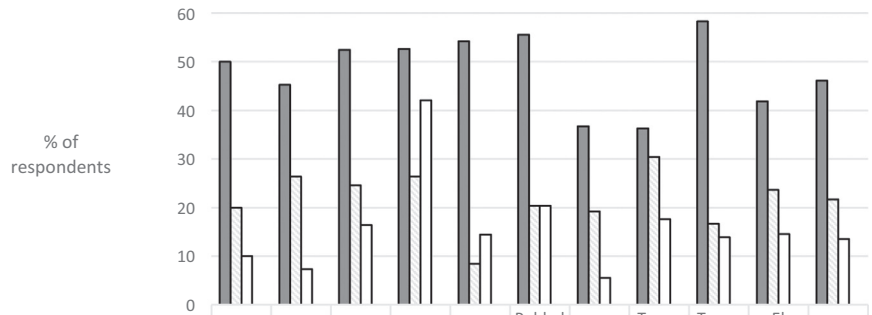
4.1. Survey data

For the survey conducted in our ten communities in Tabasco in 2015, we designed a face-to-face 63 question survey that was conducted with 664 individual households in the ten communities, which represents 91% of the total households in the community. The survey questions were specifically adapted to address the vulnerabilities in these flood prone rural communities with regard to access to education, access to financial resources and housing conditions in addition to their knowledge about the resources available in the community. Examples of the latter are risk maps, availability of shelter, information on the services and programs to help after floods that can drive their flood preparedness actions.[3] For example, in terms of resources available at the community level the question asked was: Does your community have any of the following capabilities and resources? (Some options provided were: an early warning system, community emergency plan, a shelter available during flood etc.). We ask both about access to resources and actions for preparedness because we discovered that although resources were available in the community, households were not particularly aware of it so potentially were not taking preparedness actions appropriately. We include some of these data in the statistical analysis to be described in more detail below.

In regard to the preparedness actions we specifically asked three questions in the survey on: 1) Protect Belongings: Whether the family has taken actions to protect belongings after the last flood 2) Safe Meeting Point: Whether the family has identified a safe meeting point to go to during a flood threat 3) Emergency Preparedness: Whether the family has an emergency plan or has participated in first aid training, disaster drills, or training for disaster prevention (See Table 2 for definitions of these flood preparedness actions). As discussed in section two, the existing academic literature (for example [29,33,18]) reveals that these three actions make a substantial difference in reducing the losses when severe flooding occurs, if widely adopted by households in

[2] We thank a reviewer for pointing that the characteristics of the river also affects whether the flooding actually occurs, but unfortunately we do not have data on other river characteristic.

[3] Question adaptation relied upon information obtained from the Vulnerability and Capacity Assessments conducted in the communities by the International Federation of the Red Cross and Mexican Red Cross. Everyone in the community participated in the survey except those who were not available in their homes.



	15 de Mayo	Constitución 1917	El Güiral	El_Piñal	La Esperanza	Poblado Chanero	Pueblo Nuevo	Torno Largo 2da Sección	Torno Largo 4ta Sección	El Pajanol Neuvo Mundo	Total
Protect Belongings	50.0	45.3	52.5	52.6	54.2	55.6	36.7	36.3	58.3	41.8	46.1
Safe Meeting Point	20.0	26.3	24.6	26.3	8.4	20.4	19.3	30.4	16.7	23.6	21.7
Emergency Preparedness	10.0	7.4	16.4	42.1	14.5	20.4	5.5	17.6	13.9	14.5	13.6
Total Households	50	95	61	19	83	54	109	102	36	55	664

Fig. 2. Household response to flood preparedness actions.

the community. However, as also discussed in Section 2, the degree of adoption of these actions and, more importantly, the drivers that lead to their adoption have not been as well understood. Fig. 2 provides the household responses to the three flood preparedness actions across 664 households in the ten communities we surveyed. The smallest community is 19 household responses; the largest community is 109 household responses.

On average, across these communities, we find that approximately 46% of surveyed Tabasco community households have taken actions to protect their belongings since the last flood (across all communities, the range of values is 36–58%). Approximately 22% of Tabasco community households have identified a safe meeting point (range of 8–30%) and 14% have an emergency plan or has participated in emergency preparedness trainings (range of 7–42%). We see these findings as encouraging, but they also demonstrate that much more could be done for many residents in these communities to improve their flood preparedness. Furthermore, while Fig. 2 illustrates the degree of adoption of flood preparedness actions in each of the communities, we still want to better understand what drives some rural Tabasco households to undertake these flood preparedness actions or not take these actions. We turn now to our statistical analysis of the survey data to examine this question.

4.2. Statistical methods

Our dependent variable, the three flood preparedness actions, are coded as 1 or 0, where 1 indicates that the household undertook the individual flood preparedness action, and 0 indicates that the household did not i.e.

$$yi(dependentvar) = \begin{cases} 1 & if\ the\ houehold\ undertook\ the\ flood\ preparedness\ action \\ 0 & otherwise \end{cases}$$

Given the zero-one binary structure of our dependent variables we employed a logit model in order to determine the key drivers that motivate the surveyed Tabasco households to undertake each of the three flood preparedness actions [13,48]. In our case, a binary logistic regression estimates the probability that the preparedness action is taken given the values of explanatory variables. A standard logit model can be expressed as:

$$\log(\Pr(Yi = 1|Xi = xi))$$

Where Y is the binary dependent variable (three preparedness actions) and X are the set of explanatory variables and xi is the observed value of the explanatory variables for observation i (in our case, household i).

To determine the potential set of explanatory variables to be included as flood preparedness drivers based on the responses to our 63-question survey, we referenced the academic literature on flood preparedness adoption as discussed in Section 2. Based upon this review, 30 plausible flood preparedness drivers that were assessed in the 63-question face-to-face survey emerged as applicable for our statistical analyses. We next performed a stepwise logistic regression to determine the significance level of each of these 30 candidate variables; of these, eight emerged as most relevant for the actions to protect the belongings, four for having safe meeting point and five for the emergency preparedness actions.[4] Table 2 provides the summary statistics for the explanatory variables that were statistically significant in the stepwise regression and thus included in the model.

A key finding here from simply the raw data is the lack of awareness by community residents of measures that could reduce damage prior to a flood and facilitate the recovery process afterwards. From Table 2 we find that, across these ten communities, on average, only 7.7% are aware of the flood risk maps, only 1.8% know of the early warning system in their communities, only 1% are aware of the emergency plan in their community and only 3% responded that the emergency team meets the civil protection team frequently. Fifteen percent are aware that there is availability of shelter in their community in case of flooding and 17% know that their community offers services and programs to help people after a flood. We also learned that 72% of the households share their experiences with families, 75% of the households surveyed responded that the community carried out some protective actions to protect against the risk of flooding at the household level, and 58% responded that there have been flood protective actions at the community level as well. On average there are two working family members in the households we surveyed, 92% of the respondents were severely affected by a flood in the last ten years and 34% of the households lost more than 5000 Mexican pesos during the worst flooding event.

In addition to the variables discussed above, we included in our analysis the following control variables gathered from INEGI as

[4] Variables with a significance level of greater than 10% ($p > 0.10$) were deemed nonsignificant and were removed from the analysis (see Appendix).

presented in Section 3: community center elevation in meters, distance between community center and the nearest river (Usumacinta or San Antonio) in meters, census section percentage of the population employed, census section percentage of the population over 15 years old that did not complete a primary school education, census section percentage of households with a vehicle, census section percentage of households with a radio and census section percentage of households with a refrigerator. The location variables such as elevation and distance to water body variables have been used in prior research to characterize physical vulnerability to flood hazards [35,5], and the INEGI sociodemographic variables are pertinent to social vulnerability to flood hazards. While these variables have not been extensively used in the literature (to the best of our knowledge except for the education variable), they are relevant controls to include in our analysis.

4.3. Hypotheses

To establish the hypotheses of our study we rely on the existing literature following from the literature review in Section 2. From the above studies, education is consistently a key predictor of disaster preparedness in the developing country contexts. With an assumption that knowing the flood risk map and sharing flood experiences is related to being educated about the flood risk, we test the hypotheses that:

H1. Knowledge about the flood risk map is positively related to household's preparedness actions; and

H2. Sharing the flood experiences with family has a positive impact on household's preparedness.

Both in the context of developing as well as developed nations, flood experience is found to be positively correlated with the preparedness actions. We therefore hypothesize that:

H3. Flood experiences in the past increases the likelihood of taking the preparedness actions.

Reliance on public flood protection is found to have a negative impact on preparedness action, and therefore we hypothesize that:

H4. Services and programs to help after flooding in a community are negatively correlated with the preparedness actions; and

H5. Protective actions of community at the household level are negatively correlated with the preparedness actions.

In addition to these main hypotheses we also test the impact of community capabilities and resources, such as the availability of an early warning system, availability of shelters, availability of emergency plans, and the interaction between the emergency team in the community with civil protection on the preparedness actions. The expected signs for all the variables included in the analysis are presented in Table 2.

5. Results

We ran a series of logit models to test our hypotheses regarding the drivers of adoption of flood preparedness actions. The dependent variables i.e. the preparedness actions considered are (1) actions to protect belongings, (2) know or have a safe meeting point, (3) emergency preparedness measures, and are presented in columns 1–3.

After estimating the logit regression we calculated marginal effects of each of the explanatory variables on our dependent variables (Table 3).

We find that various drivers contribute to explaining whether households will engage in preparedness actions. Given the binary structure of the preparedness actions, the marginal effect provides the probability of the preparedness activity increasing or decreasing for each statistically significant explanatory variable. For example, in column (1) confirming our Hypotheses H1 and H2, the result indicates that the probability of taking further actions to protect belongings on average increases by 16% for those who know of the risk maps in the community; and 21% for those who share experiences with family.[6] This result confirms the earlier findings by Mishra and Suar [30] that flood education (a question on whether households have seen any flood hazard maps of the community was one of the items under flood education in their survey) has a positive influence on disaster preparedness behavior in Orissa India.

As expected in H3, our column (1) model results also indicate that those

Table 3
Results of marginal effects based on logistic regressions.[5]

VARIABLES	(1) Actions to protect_belongings	(2) Have a safe meeting point	(3) Emergency Preparedness
Knowing the risk map	0.16*		
	(0.08)		
Sharing of experience	0.21***	0.09***	
	(0.04)	(0.03)	
Emergency plan available	−0.25**	0.30*	
	(0.12)	(0.16)	
Emergency team meets Civil Protection			0.11*
			(0.06)
Early warning available			0.11*
			(0.05)
Shelter available		0.15***	0.06**
		(0.05)	(0.03)
Services and programs to help after floods	0.24***		
	(0.05)		
Protective actions at HH level	0.16***		
	(0.04)		
Protective actions at community level	0.14		0.04**
	(0.19)		(0.01)
Severely affected by flood	0.34***		
	(0.06)		
Working family members		0.03*	0.01
		(0.01)	(0.01)
Lost > 5k MXN Pesos	0.12***		
	(0.04)		
Controls from INEGI included	Yes	Yes	Yes
Community fixed effects included	Yes	Yes	Yes
Pseudo r-squared	0.13	0.07	0.14
Log likelihood	−400.12	−322.36	−172.26
McFadden's Adj R2	0.085	0.017	0.039
Cragg & Uhler's R2	0.24	0.11	0.17
Pearson Chi Square	364.22	413.44	376.15
AIC	1.26	1.06	0.57
Observations	664	664	664

Robust standard errors in parentheses.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

[5] Please see appendix for odds ratio results from the logistic model

[6] Please note that the significance level of knowing the risk map is at the 10% level.

who were severely affected by flood in the last 10 years and those who lost greater than 5000 MXN during the most recent flood are likely to protect the belonging by 34% and 12% respectively (ceteris peribus). This result follows the argument that more experience with disasters, mainly floods, enhances the preparedness of people based on a learning effect that would take place among people after they experience such events [29].

Contrary to our expectations, in column (1) we find that the probability of taking further actions to protect belongings on average increases by 24% if services and programs are available in the community to help after the flood (H4). Similarly, actions to protect belongings increases by 16% if community measures to protect against the risk of flooding were undertaken at the household level, such as raised floors, palafitos (housing on stilts), tapescos (elevated platforms, for example on which to put a refrigerator), tapancos (loft for storage) which again was contrary to our expectation (H5). This result can be attributed to high-perceived risk of flooding created by community measures leading to taking preparedness actions at the household level. However, the probability of taking further actions to protect belongings however decreases by 25% if the community has an emergency plan that accounts for flood. This results is in line with our expectations and indicates a potential moral hazard effect may have occurred.[7] That is, the emergency plan may make communities feel overall safe and therefore acts as a disincentive to invest in any further protection. But more research would be necessary to understand why this negative effect occurs for only the emergency plan and not the other community action variables.

In column (2) we find that the probability that a family has or knows of a safe meeting point is increased by 9% for those who share experiences with family (H2); 30% for those who are aware of a community emergency plan that accounts for flooding; 15% for those who know that a shelter is available during floods compared to those who are unaware of the availability of shelter in their community. These results suggest that the community resources and capabilities and household's knowledge about those resources is critical in order to drive preparedness action.[8] Households should be aware of the availability of resources in the community such as shelters in order to know or have a safe meeting point.

Similarly, in column (3), in regard to preparedness action relating to emergency preparedness, different variables than those explained above appear to have a significant effect. We find that the probability of taking part in emergency preparedness increases by: 6% if a shelter is available during floods; 4% if actions to protect against the risk of flooding were undertaken at the community level; 11% if an early warning system is available and 11% if the emergency team meets frequently with civil protection. As expected the capabilities and resources in the community make the households proactive in taking preparedness actions as indicated by the significant and positive impact of shelter availability and availability of an early warning system on preparedness actions. The variable "emergency team meets civil protection" provide some notion of social network within the community which seems to have a positive impact on preparedness.

We generated a number of goodness of fits statistics for our models via the fitstat and lfit commands in STATA. From these results, we see that the McFadden R-squared is not close to zero which means that our model does predict the outcome well.

Finally, in order to further demonstrate the robustness of our results, we ran two different model specifications: (1) a model including all the 30 plausible variables listed in the Appendix below; and (2) a model excluding the variables from INEGI which are collected at the community level. Across the two different model specifications we find again that as hypothesized in H1, H2 and H3 knowing the risk map, sharing the experiences, and being severely affected by floods are again positive and significant predictors of preparedness actions. And again, contrary to our expectations in H4 and H5, services and programs to help after a flood and protective actions by the community at the household level are negative and significant predictors of taking the preparedness actions.[9]

6. Conclusions and discussions

In the face of increasing costs due to natural disasters, there have been many efforts at national, state and local levels worldwide to enhance flood resilience. There is also a wide recognition that properly preparing for a disaster before it occurs is often a cost-effective option over the long term. Preparing for disasters can include a range of activities, from building dikes and levees to buying insurance to simple avoidance measures such as protecting the belongings. In the context of poor communities, capital intensive activities such as building defense structures and buying insurance may not be viable. However, poor communities could focus on avoidance measures which do not require huge sums of capital, such as improving flood risk maps and communicating about that risk to all in the community. In order to engage more individuals in flood preparedness it is important to understand the factors that drive these actions. In this paper, we focus on poor communities in Tabasco, Mexico, and determine the drivers of flood preparedness.

Flood preparedness actions such as protecting the belongings, having a safe meeting point and emergency preparedness are some of the feasible options for these communities that we study. Past experience of the flood is found to be the biggest driver of preparedness action followed by services and programs in the community to help in case of flood, sharing of the experiences with the family, involvement of community in the reduction of effects of flooding at the household level. While the effect of flood experiences have been examined by several previous studies, our current study finds that informal sharing of experiences by the household members and the involvement of the community in flood risk reduction may make the individual households more proactive in taking the preparedness actions, which are new insights.

These results also suggest opportunities to work with communities to better select interventions that are more likely to lead to preparedness actions actually being taken. For example, our regression analyses indicate that knowing the risk maps increases people's likelihood of protecting their belongings. However, only 8% of the respondents in our study in Mexico indicated knowing the risk map in their community (about 63% of those who knew the risk maps protected their belongings). Other low respondent percentages exist for knowledge of early warning systems (2%), shelter availability (15%), and services to help after floods (17%). Better communicating this information is thus crucial. This could be done through dedicated face-to-face workshops (which has been shown to be more effective than radio or TV for instance), educating children about flooding at school, and also by taking advantage of the recent evolution of technology and the increasing penetration of smart phones even in fairly remote and poor areas.

[7] Please see Michel-Kerjan [51]. Catastrophe economics: the national flood insurance program. The Journal of Economic Perspectives, 24(4), 165–186 for how moral hazard play a role when public relief is available.

[8] A community emergency plan has a positive effect on having a safe meeting point, which is contrary to what we observed in model 1 for protecting belongings. It may be because safe meeting points are more readily discussed in implementing emergency plans than in deciding about protection of the personal belongings.

(*footnote continued*)

[9] The additional model specification results are available upon request.

Understanding the key drivers also helps resilience practitioners and change agents within communities to target their interventions to specific activities that have been shown to lead to resilience-building actions by families and communities. For example, sharing experiences of previous floods is positively related to two of the key preparedness actions (protect belongings, have a safe meeting point) that families can take to increase their resilience to floods. Risk management activities should thus ensure that interventions include sharing the information regarding the risk maps through awareness campaigns and also educating households that it is imperative to share experiences with their family members as this will contribute to more households taking preparedness action. We also see evidence that community level protective actions already in place, such as community embankments, lead to better individual household flood preparedness. This result seems somewhat counterintuitive but may have resulted from high perceived risk of floods triggered by such community measures. For those working on the ground in these communities as well as the other stakeholders responsible for flood risk management these are important findings for planning the interventions that would lead to proactive participation of individuals in the community.

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Appendix A

See Table A1.

Table A1
List of 30 plausible explanatory variables.

	Explanatory variables included in stepwise regression	Question #	Significant (protect belongings)	Safe meeting point	Emergency preparedness
1	Years lived in the community	3			
2	Know the risk maps	15	Yes		
3	Share experience	19	Yes	Yes	
4	Severely affected (yes) –loss of livelihood	12/13	Yes		
5	Severely affected (yes)- property damage	12/13			
6	Severely affected (yes – minor injury	12/13	Yes		
7	Help neighbors	34			
8	Help received				
9	Link with other communities				
10	Received visit –related to care of water and sanitation	37B			
11	Received visit – health related (dangue fever, cough, flue etc)	37C			
12	Has the work been realized for the betterment of community - services of water, sanitation and electricity	38A			
13	Maintenance and improvements of road	38B			
14	Transportation system	38C			
15	Market, food supply or national program of food distribution	38D			
16	Health center	38E			
17	Capabilities and resources to – early warning system available	39A			Yes
18	Community emergency plan	39B		Yes	
19	Community emergency team	39C			
20	Emergency team meet with civil protection	39D			Yes
21	Shelter in case of flood	39F		Yes	Yes
22	Have a phone to make calls in case of emergency	41			
23	Community offer services and program to help after flood	50	Yes		
24	Loan During Flood				
25	Working family members	53		Yes	Yes
26	Monthly approximate income	55			
27	Monthly income affected	57			
28	How much is lost during the worst flood ($)	56	Yes		
29	Actions carried out by community –at your HH level	40A/B/C/D/E	Yes		
30	Actions carried out by community- at community level	40F/M	Yes		Yes

Appendix B

See Table B1.

Table B1
Odds ratio Results from logistic Regression.

VARIABLES	(1) Actions to protect belongings	(2) Have a safe meeting point	(3) Emergency preparedness
Knowing the risk map	0.607*	0.373	0.597
	(0.366)	(0.378)	(0.499)
Sharing of experience	0.934***	0.618**	−0.0148
	(0.212)	(0.262)	(0.358)
Emergency plan available	−1.2158**	1.165*	0.899
	(0.779)	(0.649)	(0.657)
Emergency team meet civil protection	0.0515	−0.592	1.003*
	(0.515)	(0.568)	(0.529)
Early Warning available	0.150	0.543	1.495*
	(0.574)	(0.614)	(0.879)
Shelter available	−0.0234	0.999***	0.938**
	(0.252)	(0.255)	(0.333)
Services and Programs to help after floods	0.935***	−0.260	−0.360
	(0.240)	(0.287)	(0.430)
Protective action at HH level	0.660***	0.185	−0.264
	(0.206)	(0.244)	(0.358)
Protective action at community level	0.591***	−0.0267	0.820**
	(0.188)	(0.216)	(0.341)
Severely affected by flood	1.851***	0.317	−0.888
	(0.495)	(0.468)	(0.483)
Working family members	−0.112	0.221**	0.190
	(0.112)	(0.106)	(0.170)
Lost > 5k MXN Pesos	0.571***	−0.287	−0.368
	(0.198)	(0.245)	(0.353)
	(62.75)	(82.51)	(119.6)
Controls from INEGI included	Yes	Yes	Yes
Community Fixed Effects included	Yes	Yes	Yes
Pseudo R2	0.13	0.07	0.14
Log likelihood	−400.12	−322.36	−172.26
McFadden's Adj R2	0.085	0.017	0.039
Pearson Chi Square	364.22	413.44	376.15
Observations	664	664	664

Robust standard errors in parentheses.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

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