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Household adjustment to flood risk: a survey of coastal residents in Texas and Florida, United States

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Individual households have increasingly borne responsibility for reducing the adverse impacts of flooding on their property. Little observational research has been conducted, however, at the household level to examine the major factors contributing to the selection of a particular household adjustment. This study addresses the issue by evaluating statistically the factors influencing the adoption of various household flood hazard adjustments. The results indicate that respondents with higher-value homes or longer housing tenure are more likely to adopt structural and expensive techniques. In addition, the information source and the Community Rating System (CRS) score for the jurisdiction where the household is located have a significant bearing on household adjustment. In contrast, proximity to risk zones and risk perception yield somewhat mixed results or behave counter to assumptions in the literature. The study findings provide insights that will be of value to governments and decision-makers interested in encouraging homeowners to take protective action given increasing flood risk.

Keywords: floods, household adjustments, mitigation, survey

Introduction

Increasing physical risk combined with rapid land use change and development in flood-prone areas has amplified the adverse impacts of flooding in the United States. Never before have the repercussions of both surge and rainfall-based storms been so damaging to the economic vitality of local communities. Losses owing to acute and chronic flooding are especially problematic in low-lying coastal areas, where development has accelerated in recent decades. The average amount of flood-related property damage per annum has risen approximately 54 times over the past four decades (Brody, Highfield, and Kang, 2011). Property owners in the US claimed more than USD 3.5 billion per year in insured flood-related losses between 2003 and 2013 alone.

While historically the federal government has shouldered the financial burden of flood risk reduction and recovery through disaster aid and large engineering projects, households are encouraged ever more to implement individual mitigation techniques to reduce the adverse effects of flooding on their property. Deteriorating flood protection infrastructure, dwindling federal resources for new projects, an overall lack of political will to initiate large-scale construction projects, and sprawling patterns of development in coastal regions are making it difficult (if not impossible) for governments to protect comprehensively homeowners and to restore flood-affected property. The responsibility for protecting the homes and lives of the members of the US population thus will rest increasingly in the hands of the individual.

Some work has been conducted on flood mitigation techniques at the community level (Brody and Highfield, 2013; Highfield and Brody, 2013), but little observational research has been done at the household level where the financial and psychological consequences are felt the most. There are various studies on insurance purchasing behaviour (see, for example, Lindell, 2013; Grothmann and Reusswig, 2006), but less is known about the degree to which homeowners select from among a range of flood mitigation techniques and the factors contributing to these choices. In response to this lack of information, this study surveyed coastal residents in four localities in the US States of Texas and Florida to addresses the following two research questions:

- to what extent are households in Texas and Florida adjusting to the risk of floods; and
- what are the major factors driving the decision to implement a specific type of mitigation technique?

First, descriptive statistics show the frequency at which households implement eight structural and non-structural mitigation techniques. Second, using binary logistic regression models that control for socioeconomic, perception, and proximity-based variables, the major factors contributing to the selection of a particular household adjustment are identified. The findings provide insights into how and why residents protect their homes from the threat of flooding.

The second section reviews existing work on household adjustment to flood risk, with special attention on the factors contributing to mitigation decisions. The third section contains a description of the research methods for the study, including the survey sample, concept measurement, and analysis of the data. The fourth section reports on the results of the descriptive statistics and the logistic models and their implications for policymaking. The fifth section concludes with a summary of the findings and suggestions for future research on household adjustments to flood risk and flood mitigation in general.

Context and literature

Flood hazard adjustment techniques

Traditional flood mitigation techniques involve structural interventions, such as dams and levees, implemented by governments at the community or regional level (Birkland et al., 2003). In more recent times, however, individual households have increasingly borne responsibility for protecting structures and property. Flood mitigation at the household level (that is, household adjustment to flood risk) has become more ubiquitous over the past several decades because of government regulations, incentives, outreach programmes, and a mounting sense of personal efficacy on the part of property owners (Laska, 1986). Household hazard adjustment is defined as 'those actions that intentionally or unintentionally reduce risk from extreme events in the natural environment' (Lindell, 1997, p. 328)—see also Burton, Kates, and White (1993) for more information on the definition of household hazard adjustment. Consequently, hazard adjustments include hazard mitigation (to decrease property damage) and preparedness (to reduce casualties), as well as hazard insurance purchase (to redistribute financial losses).

Household adjustments to hazards include a broad spectrum of activities, ranging from expensive structural modifications to simply gathering information on the nature of flood risk in a particular neighbourhood. Household flood mitigation techniques can be classified according to required costs (Kreibich et al., 2011). For instance, construction-based techniques, such as raising a structure above the Base Flood Elevation (BFE), are effective in avoiding inundation (Highfield and Brody, 2013), but they may entail expenses that many homeowners cannot afford (Lindell and Hwang, 2008). In contrast, adjustments that rely on behavioural modifications, such as storing valuables on the second floor of a home, require little or no outlay or structural reconfiguration.

Three categories of techniques are derived by using overall investment costs (such as effort, expense, and time) to classify and study household mitigation of flood risk:

Table 1. Household adjustment techniques to counter flood risk

Mitigation techniques	Descriptions
Structural and expensive	
Elevation	Elevating the entire house or constructing a new, elevated floor within the house.
Earthen berms	Erecting a small barrier around a house to keep water from reaching a building.
Flood-proof (dry)	Adding a waterproof veneer to the exterior walls; sealing doors to prevent water from entering.
Behavioural with minor modifications	
Flood-proof (wet)	Intentionally allowing floodwaters to enter to protect the building from structural damage caused by differences in internal and external water pressure.
Second-floor storage	Moving valuables and service equipment to the second floor to minimise flood damage.
Information gathering and exchange	
Flood insurance	Purchasing flood insurance.
Contact agencies	Contacting agencies for flood hazard information.
Attend meetings	Attending meetings to learn about flood hazards.

Source: FEMA (2005).

- structural and expensive;
- behavioural with minor modifications; and
- information gathering and exchange (see Table 1).

Structural techniques include elevating a structure (usually above the BFE), constructing earthen berms, and dry flood-proofing a home to prevent water from entering. Behavioural modifications entail wet flood-proofing where water can enter a home, but critical services are relocated out of harm's way and valuables are stored above ground or on the second floor. Adjustments relying purely on information gathering and exchange include purchasing insurance, attending meetings, communicating with governmental agencies, and other activities that seek to procure information to raise household awareness of flood risk. These types of adjustments require the least amount of financial expenditure and commitment, but nevertheless may help to reduce effectively flood-related losses in the long term.

Factors influencing flood hazard adjustment

Better understanding of the factors that trigger the adoption of flood risk household adjustments can help communities to implement programmes that target the needs of local residents and assist them in preparing for and decreasing the impacts of flooding in the long term. Research has been conducted on the predictors of household flood hazard adjustment, especially the purchase of insurance under the Federal Emergency Management Agency (FEMA)'s National Flood Insurance Program (NFIP), established in 1968 (see, for example, Lindell, 2013). However, studies of household hazard adjustment need to address multiple activities because the perceived need for one class of hazard adjustment might be reduced by the adoption of others. For instance, people's perceptions of the need to purchase hazard insurance could be easily diminished by their adoption of (what they consider to be) 'adequate' hazard mitigation and emergency preparedness actions.

A variety of factors have been identified as being important predictors of household hazard adjustment, including hazard experience, hazard intrusiveness, location in relation to physical risk, risk perception, and socioeconomic characteristics. These factors can be divided broadly into the following five categories (as discussed in more detail below): proximity; socioeconomic characteristics; perception; social context; and contextual controls.

Proximity

Hazard proximity, the distance to a hazard risk zone, is considered to be one of the main predictors of household adjustment because it relates to perceived risk (Zhang et al., 2010). Although, as Lindell (2013) notes, hazard proximity is a potentially important explanatory variable, it is frequently ignored by many researchers because it has been difficult to measure. The availability of geographic information system (GIS) technology and spatially referenced data has reduced this impediment. Researchers have begun to examine proximity issues (Bollens, Kaiser, and Burby, 1988; Zahran et al., 2009) by showing that increasing proportions of floodplain areas are associated with the adoption of hazard insurance. An early study by Waterstone (1978) took a more spatially-specific approach by measuring horizontal distances from streams and the FEMA-designated 100-year floodplain. The results indicated an inverse relationship between distance from the nearest stream and floodplain and the adoption of insurance. Montz (1982) followed-up on these proximity measures in a study of residents in Broome County, New York. She confirmed a decreasing rate of insurance purchase further away from the 100-year floodplain, but in contrast found higher levels of insurance adoption farther away from the nearest stream. Lindell and Hwang (2008) were the first to control for multiple demographic and household characteristics in their assessment of the effects of proximity. They found that proximity to inland flood and coastal hurricane hazards was significantly related to flood insurance purchase. None of these studies, though, accounts completely for adjacent development, hydrological conditions, or topography, nor do they focus on insurance adoption outside of designated risk zones.

Socioeconomic characteristics

Socioeconomic and demographic characteristics have also been used to predict household hazard adjustments, although the direction and significance of the findings are mixed (Lindell, 2013). Factors such as age, community tenure, education, ethnicity, gender, homeownership, income, and marital status may all affect an occupant's decision to take protective measures. Peacock (2003) confirmed that income and ethnicity are critical indicators of households' hazard adjustment by showing that lower income and black households have significantly lower quality shutter and envelope coverage as compared to higher income and Anglo households. In the same sense, Collins (2008) reported that lower income and renter households have significantly less wildfire mitigation measures than higher income and homeowner households. Furthermore, Browne and Hoyt (2000) insisted that households' income and the price of insurance are the most critical determinants in decisions on flood insurance purchasing. Meanwhile, Terpstra and Lindell (2013) found that gender has an indirect impact on intention to adopt hazard adjustments and females have stronger risk perceptions than males. Peacock (2003) also discovered that years in residence have significantly positive effects on households' hurricane mitigation activities. Lastly, Grothmann and Reusswig (2006) found a significant correlation between age, homeownership, and household income and flood protection response.

Risk perception

Myriad researchers have analysed risk perceptions as a major predictor of the adoption of various kinds of hazard adjustments (see, for example, Lindell and Hwang, 2008). A risk perception can be defined as 'people's expectations about the probability of the occurrence of an extreme environmental event of a specific intensity at a particular place within a given period of time' (Lindell, 2013, p. 112). In this sense, flood risk perception can be understood as the perceived danger of personal consequences owing to inundation. It is one of the strongest and most-studied factors influencing hazard adjustment in general, and flood insurance purchase in particular. For instance, Preston, Taylor, and Hodge (1983) reported a significant correlation between flood risk perception and home modifications. Similarly, Laska (1990) found a significant correlation between expected flood damage and a coping index. More recently, Blanchard-Boehm, Berry, and Showalter (2001) observed that expected personal damage was positively correlated with flood insurance purchase. In addition, in a study of 66 households that suffered a flood in 1997, Zaleskiewicz, Piskorz, and Borkowska (2002) showed that insurance decisions were related to a few basic psychological factors associated with risk perception. Grothmann and Reusswig (2006) revealed significant correlations between protective behaviours towards flooding and personal flood risk perception in Germany. Lindell and Hwang (2008) reported significant correlations between expected property damage and flood insurance purchase.

It is important to note, however, that, in a comprehensive literature review, Bubeck, Botzen, and Aerts (2012) pinpointed a weak statistical relationship between risk perception and private mitigation measures. The authors suggest that high risk perceptions need to be coupled with a belief in being able to cope with or to avoid flood risk. Moreover, the observational literature has not considered adequately the possibility that previously adopted mitigation measures can lower risk perceptions.

Social context

Perceptions of flood risk and subsequent protective action measures also are influenced by the type and source of hazard information reaching the household, and the degree to which they are trusted (Chaffee, 1982; Lindell and Hwang, 2008; Lindell and Perry, 2012). Sources embedded within a broader network will transmit information on risk and provide guidance on how to reduce the adverse impacts of a flood event (Lindell, 1997). Governmental authorities, news media outlets, and friends, neighbours, and relatives can all be critical sources of flood hazard information that can lead to protective action at the household level. Information can be received directly from an original source, or filtered through multiple sources (Rogers and Sorensen, 1988). Risk information can also be transmitted through various channels, including electronic and print conduits and face-to-face encounters, each with its own rate of dissemination, precision, and effect on household behaviour. Sources of information can be formal, such as government brochures or websites, or informal, such as personal connections. According to Chaffee (1982), information convergence (when different channels provide the same message), increases a person's confidence in that message. When information is divergent, one must make the decision about which message to believe. When this occurs, people are inclined to listen to messages from multiple sources, eventually deciding to believe the most convergent.

Contextual controls

Experience of flooding is another major factor that influences household adjustment. Generally, the more recent and severe the event, the more likely a household is to make an adjustment. For instance, Baumann and Sims (1978) and Laska (1990) all find significant correlations between flood experience and flood insurance purchase. Blanchard-Boehm, Berry, and Showalter (2001) reported increased insurance purchases after a flood: from 52 per cent at the time of the event to 62 per cent six months later, when their survey was administered. Similarly, Browne and Hoyt (2000) found that flood insurance purchases are highly correlated with flood-related losses in the previous year. Zahran et al. (2009) confirmed this conclusion in their study of NFIP flood insurance purchase in Florida, where both preceding flood property damage and the frequency of flooding predicted the number of policies across the state from 1999–2005. Kreibich et al. (2011) demonstrated that flood events on the Elbe River in Germany significantly boosted households' adjustment activities, such as 'flood adapted interior fitting', 'shield with water barriers', and 'install heating or other utilities upstairs'. Lindell and Hwang (2008) also discovered that, as predicted, flood experience has an indirect effect on flood insurance purchase, which was mediated by risk perception.

In addition to personal traits, household adjustment to flood risk can also be influenced by external government and community-level initiatives. For example, the NFIP has become the primary vehicle for providing flood insurance to residents and businesses. Households in participating NFIP communities are required to purchase flood insurance if they are located within a Special Flood Hazard Area (SFHA) (that is, the 100-year floodplain) and have federally-backed mortgages. At the end of 2013, the NFIP had more than 24,700 participating communities and approximately 5.48 million flood insurance policies in force covering in excess of USD 1.28 trillion in assets,[1] the majority of which were located in Texas and Florida (FEMA, 2010).

One important component of the NFIP is the CRS, which was initiated in 1990 as a way to encourage communities to exceed the NFIP's minimum standards for floodplain management. Communities participating in the CRS receive federal flood insurance premium discounts in exchange for adopting various flood mitigation measures. The non-structural orientation of the CRS programme categorises planning and management activities in four series containing 18 mitigation activities. Credit points are aggregated into classes, where communities awarded a higher CRS class have implemented a larger number and a wider scope of flood mitigation measures. Insurance premium discounts range from 5 per cent in Class 9 to 45 per cent in Class 1 (Brody and Highfield, 2013).

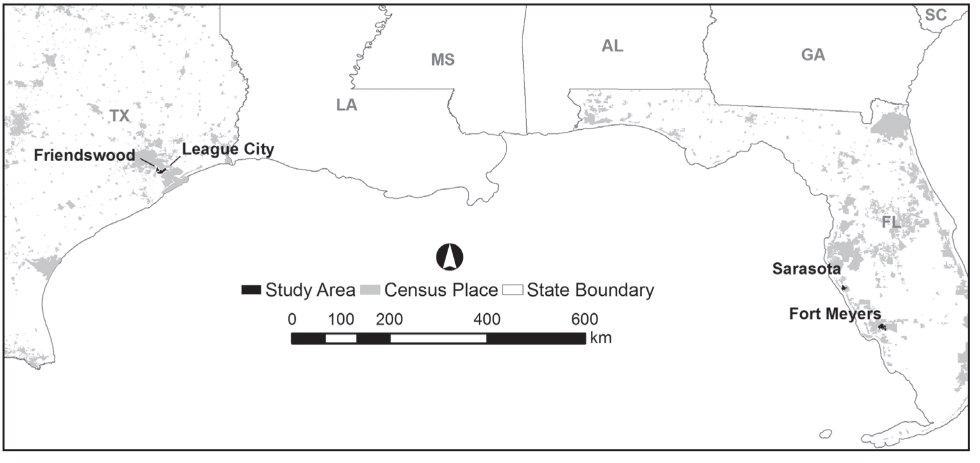
As noted, the adoption of household flood adjustment takes place in a social context and the characteristics of local governments can affect the decision-making process of households. In particular, CRS public information and outreach activities (Series 300) include specific actions taken by local governments that can help residents to increase their awareness of flood risk. These actions include dissemination of risk information, hazard information disclosure during real-estate transactions, technical assistance, and community flood risk reduction workshops. A household located in a jurisdiction with a high CRS score may be more likely to adopt flood adjustments. Zahran et al. (2009) examined the extent to which household insurance purchases are influenced by local governments' mitigation activities under FEMA's CRS programme, and discovered a significant relationship between NFIP policies per 100 households and communities' CRS points. They reported, too, that a one per cent rise in CRS points earned is associated with an increase of 0.129–0.292 per cent in the number of NFIP policies per 100 households. More recently, Highfield, Brody, and Blessing (2014) assessed the effect of CRS activities on reducing flood damage at the parcel level, and found that these public information activities actually save property owners significant amounts of flood damage. They assumed that the activities in Series 300, such as critical information on flood hazard, educational projects, and technical assistance, might have influenced behavioural changes among homeowners that led to reduced losses in the long term.

Methods

Sample selection

Two communities within coastal Texas (Friendswood and League City) and the west coast of Florida (Sarasota and Fort Meyers) were selected for analysis. These jurisdictions were chosen based on their class rating within the CRS, which serves as an indicator of the level of effort a community invests in flood mitigation. Each state contains a community with a high CRS score (Friendswood, TX, and Sarasota, FL, are Class 5) and a comparatively low CRS score (League City, TX, and Fort Meyers, FL, are Class 7). Jurisdictions also have roughly equivalent population sizes

Figure 1. Coastal community study area



Source: authors.

of between 20,000 and 100,000 and share similar hydrological, elevation, and flood risk profiles associated with the Gulf of Mexico coast.

Next, a stratified random sample of 500 parcels within each community was identified using the following flood zones: (i) within the FEMA-designated 100-year floodplain; (ii) within the FEMA-designated 500-year floodplain; and (iii) within the X-zone (an area of minimal flood hazard or outside of the 500-year floodplain). This procedure generated a total sample of 2,000 households. A postal survey was administered in spring 2013 to this sample following procedures specified by Dillman (2000). In total, three complete waves of surveys were sent to households in the sample, plus a reminder card after the first wave. The average response rate was 17.38 per cent overall: 12 per cent for Sarasota; 15.6 per cent for Fort Meyers; 24.4 per cent for Friendswood; and 17.5 per cent for League City. The overall study sample thus was composed of 351 respondents.

Concept measurement

The dependent variables for the study were measured dichotomously based on the number of respondents adopting eight different household mitigation techniques, including construction-based or structural modifications, such as the elevation of homes, assembly of earthen berms, and dry-proofing of a structure to prevent the infiltration of water. Also examined were household adjustments that require behavioural modifications, such as wet-proofing a home, moving critical equipment to a higher location, and storing valuables on upper floors to prevent water damage. Finally, the following three non-structural adjustments based mostly on information gathering and exchange were analysed: purchase of insurance; contacting governmental agencies for information on flood hazards; and attending meetings to learn about flood hazards.

Independent variables were calculated and evaluated along four dimensions: proximity; socioeconomic characteristics; perception; and contextual controls (see Table 2). Under proximity, distance to the coast and distance to the nearest stream were measured for each respondent, using a GIS. In addition, the respondents' floodplain location was calculated via a dichotomous measure based on the 100-year floodplain. Each variable was measured as the straight-line distance in metres from the centroid of the parcel to the point of interest. Floodplain locations were determined using FEMA-digitised mapping products, constituting the most detailed available data on the entire study area. Coastline and stream segment features were calculated using the National Hydrography Dataset (NHD) assembled by the United States Geological Survey (USGS).

Two socioeconomic variables were measured and assessed within the statistical models. First, the tax-assessed improvement value (log transformed) for the address of each respondent was calculated as an economic control variable. Second, housing tenure was incorporated in the analysis based on the reported number of years a respondent had lived in his/her present home. The mean housing tenure for the survey was 12.51 years (see Table 2).

Table 2. Concept measurement

Variable	N	Mean	Standard deviation	Range	Source
Proximity					
Coast distance*	351	9.15	5.84	0–23.30	NHD
Stream distance*	351	0.358	0.328	0–2.80	NHD
Outside of floodplain	351	0.86	0.344	0–9164.40	FEMA
Socioeconomic characteristics					
Improvement value	351	12.98	1.56	10.26–16.04	Appraisal district
Housing tenure	334	12.51	11.50	1–58	Survey
Perception					
Flood risk perception	322	14.59	4.28	6–30	Survey
Social context					
Information from media	320	13.25	3.72	5–25	Survey
Information from people	326	6.93	3.72	3–15	Survey
Contextual controls					
Flood experience	336	1.86	1.49	0–6	Survey
CRS	351	0.52	0.49	0–1	FEMA

Notes: * In kilometres.
Source: authors.

A risk perception control variable was measured by combining six survey questions asking respondents about the likelihood of a flood in the next 10 years that will cause: (i) major damage to property in your city; (ii) deaths and injuries to people in your community; (iii) major damage to your home; (iv) injury or death to you or members of your immediate family; (v) disruption to your job that prevents you from working; and (vi) disruption of electrical, telephone, and other basic services. Each question was ranked on an ordinal scale from 1–5, where 1 and 5 represent 'not at all' and 'to a very great extent', respectively. The combination of these six items yielded a Cronbach's alpha of 0.85 and the resulting risk perception variable was thus on a scale from 6–30.

Also included in the model was a variable gauging experience of the consequences of flooding. Respondents were asked whether the following impacts had occurred: (i) your immediate family's property has been damaged in a flood; (ii) you have been injured or an immediate family member has been killed or injured in a flood; (iii) you have experienced disruption to your job that prevents you from working; (iv) you have experienced disruption to your shopping and other daily activities; (v) the property of a friend, relative, neighbour, or co-worker you know personally has been damaged in a flood; and/or (iv) a friend, relative, neighbour, or co-worker you know personally has been killed or injured in a flood. These six dichotomous items were combined into a single variable (Cronbach's alpha of 0.75) on a scale from 0–6, where 0 and 6 represent 'no experience' and 'multiple adverse experiences', respectively.

Two independent variables were measured for the source of flood hazard information: the media; and personal contacts. Five survey items asking respondents about the extent to which they obtain information on flood hazards were combined to derive a media-source variable: (i) newspapers; (ii) television; (iii) radio; (iv) internet; and (v) brochures. Each question was ranked on an ordinal scale from 1–5, where 1 and 5 represent 'not at all' and 'to a very great extent', respectively. The combination of these five items (Cronbach's alpha of 0.67) yielded a variable on a scale from 5–25. A personal contact variable was calculated by combining the following three survey items asking respondents from where they receive flood hazard information: (i) meetings; (ii) friends, relatives, neighbours, and co-workers; and (iii) personal experience and observation (Cronbach's alpha of 0.65). As above, each question was rated on a scale from 1–5, where 1 and 5 represent 'not at all' and 'to a very great extent', respectively, to produce a variable on a scale from 3–15.

Finally, a dichotomous control variable for high and low CRS points was calculated, indicating the strength of mitigation measures at the jurisdictional level. Friendswood, TX, and Sarasota, FL, are both Class 5 jurisdictions and are considered to have high levels of mitigation. In contrast, League City, TX, and Fort Meyers, FL, are Class 7 jurisdictions (at the time the survey was conducted), which is considered to be on the lower end of the mitigation spectrum.

Data analysis

The data were analysed in two phases. First, simple descriptive statistics were employed to assess the degree to which different household adjustments were selected. Second, binary logistic regression models were utilised to predict the odds of a respondent choosing each of the eight mitigation techniques listed above. Since residents were sampled randomly within only a subset of primary sampling units (that is, cities), statistical errors were assumed to be correlated within each of the four selected cities, leading to analysis of the logistic models using clustered standard errors, as is typical of this type of study design (Kish, 1965). Several diagnostic tests were performed, including multicollinearity, goodness of fit, and autocorrelation.

Results

The survey responses revealed that non-structural approaches to household mitigation are relied upon significantly more than structural approaches. Purchasing flood insurance is by far the most frequently reported form of household adjustment among residents in the four sampled jurisdictions (see Table 3). More than 67 per cent of respondents had purchased insurance, which may be required by FEMA if the home

Table 3. Mean response for household flood hazard adjustments

Variable	Observations	Mean
Elevation	335	0.113
Earthen berms	339	0.021
Flood-proof (dry)*	342	0.026
Flood-proof (wet)**	340	0.065
Second-floor storage	325	0.228
Insurance purchase	345	0.678
Contact agencies	343	0.087
Attend meeting	343	0.140

Notes: * A dry-proofed building is sealed against floodwaters. All areas below the flood protection level are made watertight. For instance, walls can be coated with waterproofing compounds or plastic sheeting. Openings such as doors, windows, sewer lines, and vents are closed with removable shields or with sandbags. ** A wet-proofed building intentionally allows floodwaters into the building to minimise water pressure on the structure. As a result, the loads imposed on the house during a flood, and therefore the likelihood of structural damage, may be reduced greatly. This method also involves moving valuables and service equipment to a higher location.

Source: authors.

is inside the 100-year floodplain and has a mortgage.[2] League City, TX, had the highest number of respondents citing insurance as a mitigation tool. This result is supported by the fact that League City contains the most NFIP policies (16,044) and number of respondents located within the SFHA among the four sample jurisdictions. The substantial use of insurance as a household adjustment is consistent with the national emphasis on recovery as a way to cope with the threat of flooding. As of September 2014, for example, there were 5.3 million NFIP policies in force, totalling USD 1.3 trillion of coverage.[3] Storing valuable items on the second floor of a home is the second most popular adjustment, cited by more than 22 per cent of survey respondents. Again, League City, TX, residents reported the most frequent use of this mitigation approach as compared to the other three study jurisdictions. Elevating homes out of the 100-year floodplain (11 per cent of respondents) and attending meetings to learn more about flood hazards (13 per cent of respondents) are the next most heavily used household adjustments to flood risk. The remaining techniques examined in the study received much less attention (less than 7 per cent) by survey respondents (see Table 3).

The correlation matrix (see Table 4) indicates the strength of associations between all dependent and independent variables measured in the study. As expected, several household adjustments are significantly correlated, particularly within the categories of structural, behavioural, and information-based. There are three significant correlations among independent variables that are worth noting. First, high CRS scores are strongly associated with longer household tenure, more flood experience, and being within the 100-year floodplain (on which the programme is based). Second,

Table 4. Correlation among variables

	Elevation	Earthen berms	Flood-proof (dry)	Flood-proof (wet)	Second-floor storage	Flood insurance purchase	Contact agencies for information	Attend meetings
Elevation	1							
Earthen berms	0.0958	1						
Flood-proof (dry)	0.1905*	0.1140*	1					
Flood-proof (wet)	0.0598	0.0484	0.2545*	1				
Second-floor storage	0.0902	-0.0294	0.1501*	0.1680*	1			
Flood insurance purchase	0.078	0.009	0.0723	-0.0014	0.1136*	1		
Contact agencies for information	-0.0448	0.1037	0.0133	0.0442	0.1410*	0.0726	1	
Attend meetings	-0.0073	0.0011	0.0382	0.0301	0.1643*	0.0369	0.3504*	1
High CRS score	0.0362	0.0118	0.0819	0.0564	0.021	0.1561*	0.0448	0.081
Assessed value	0.1567*	-0.0105	0.1332*	0.0646	0.1092*	0.4257*	0.0022	0.1114*
Tenure	-0.0607	-0.0114	0.0706	-0.0715	-0.1299*	0.0605	-0.0314	0.0302
Flood experience	-0.0144	0.0412	0.1039	0.1780*	0.1179*	0.2927*	0.1327*	0.0936
Risk perception	-0.1027	-0.0682	0.0033	0.0564	0.0593	0.1545*	0.1399*	0.1933*
Out of floodplain	0.0641	-0.0009	0.0176	0.0112	0.0452	-0.2646*	-0.066	-0.0492
Distance from coast	0.1169*	0.0277	0.05	-0.0607	0.035	-0.0755	-0.1283*	-0.0182
Distance from stream	-0.019	-0.0652	0.027	0.1277*	-0.0183	-0.0044	0.0242	-0.0343
Information from media	0.0506	0.0132	0.1164*	-0.0197	0.0261	0.1313*	0.0322	0.1379*
Information from people	0.0877	0.1142*	0.0941	0.032	0.1561*	0.2153*	0.2577*	0.3312*

Note: * $p<0.05$.

Source: authors.

respondents living in more expensive homes have much more flood experience, possibly because they are living close to the floodplain where environmental amenities pervade. Third, those with more flood experience and living in close proximity to objective risk zones appear to have a higher perception of flood risk and to share this information with other people, such as neighbours and relatives.

Binary logistic regression models with reported odds ratios (see Table 5) elucidate which factors are most influential in the decision to implement a specific household adjustment in response to flood risk. Assessed home value is the primary statistical

Table 4. Cont.

High CRS score	Assessed value	Tenure	Flood experience	Risk perception	Out of floodplain	Distance from coast	Distance from stream	Information from media	Information from people
1									
0.0188	1								
0.3060*	-0.1111*	1							
0.2859*	0.3346*	0.1458*	1						
0.0106	0.1281*	-0.0033	0.3058*	1					
-0.4537*	-0.2354*	-0.2314*	-0.3053*	-0.1635*	1				
-0.1821*	-0.0034	-0.0742	-0.0276	-0.1069	0.4429*	1			
-0.0581	-0.0676	-0.0048	0.0291	0.0222	0.1243*	-0.2418*	1		
-0.024	-0.0257	-0.0221	0.072	0.1707*	0.0335	0.0087	0.0735	1	
0.0575	0.2359*	0.0259	0.3293*	0.2687*	-0.0987	0.0349	0.0064	0.3570*	1

driver ($p<0.01$) for elevating a home so that it is no longer within the 100-year floodplain. Respondents with higher-valued homes and corresponding financial capacity are more than 1.6 times more likely to raise their structure above the BFE. Acquiring information on floods from friends, relatives, neighbours, and other people also is a significant ($p<0.001$) predictor in the decision to elevate homes—one should note that local jurisdictions may require elevation above the BFE for new homes built within a floodplain. Higher perceptions of risk lead to a decreased probability that a homeowner will elevate his/her structure—consistent with the analysis of Weinstein

Table 5. Binary logistic regression models predicting household flood mitigation

	Model 1 Elevation	Model 2 Earthen berms	Model 3 Flood-proof (dry)	Model 4 Flood-proof (wet)	Model 5 Second-floor storage	Model 6 Flood insurance purchase	Model 7 Contact agencies for information	Model 8 Attend meetings
High CRS score	1.153	0.809	0.077 (-)	0.829	1.27	1.669***	1.517***	1.902***
Assessed value	1.655**	0.771	13.009***	1.945***	1.086	1.911***	0.676*** (-)	1.047
Flood experience	0.862	1.241	1.261	2.546	1.124	1.074	1.518**	0.99
Risk perception	0.886* (-)	0.782	0.906 (-)	0.986	1.001	1.038	1.033	1.019
Tenure	0.994	1.029***	1.114	0.863*** (-)	0.955*** (-)	1.022**	0.967	0.996
Outside of floodplain	0.436 (-)	0.356** (-)	---4	0.328	0.647*** (-)	0.149* (-)	1.809	1.196
Distance from coast	1.092	1.018	1.641*	1.048	1.016	0.996	0.912*** (-)	0.971*** (-)
Distance from stream	2.058	0.018*** (-)	9.885	4.599	1.384	0.861	0.275	0.647
Information from the media	1.044	0.975	1.272	1.016	0.96	1.085***	0.904	1.053
Information from people	1.194***	1.708*	1.104	0.864	1.156***	1.039*	1.559***	1.462**
Pseudo R^2	0.127	0.254	0.369	0.267	0.059	0.218	0.2	0.148

Notes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$.

Source: authors.

and Nicolich (1993) of the problems inherent in trying to assess this relationship using cross-sectional data. Proximity variables, by contrast, do not have a significant effect on elevation as a mitigation tool.

The decision to build earthen berms (Model 2) around one's home to protect it from flooding appears to be driven by a different set of factors. For instance, housing tenure is a significant predictor ($p<0.001$): residents who have lived in their home for longer periods of time are more likely to undertake extensive construction. Obtaining hazard information from acquaintances (as opposed to the media) is also an important factor ($p<0.05$) in the decision to erect protective berms. In addition, proximity variables contribute appreciably to a respondent's decision: those living farther away from streams and outside of the SFHA are significantly less likely to assemble earthen berms for protection.

Dry-proofing (Model 3) an entire home so water cannot infiltrate the structure also requires expensive changes (similar to elevation). As such, this mitigation technique is highly influenced by home value ($p<0.001$). Respondents living further away from the coastline are also more likely to pursue this flood hazard adjustment—homes close to the water are more likely to be elevated for storm-surge protection, potentially making dry-proofing unnecessary. In contrast, wet-proofing (Model 4) requires more behavioural modifications, such as moving utilities to a higher location. While home value is still an important factor ($p<0.001$), housing tenure comes into play when analysing this mitigation technique. Those living in their home for only a short time (negative coefficient) are more likely to embrace the use of wet-proofing to reduce flood-related losses. Housing tenure also has a negative effect ($p<0.001$) on storing valuables on the second floor of a home (Model 5), a technique that relies almost entirely on behavioural adjustments. Obtaining hazard information from acquaintances is another major driver behind the selection of this household mitigation activity, as is distance from the floodplain ($p<0.001$).

The remaining household flood adjustments (see Table 4) are entirely non-structural, requiring no reconfiguration of buildings and relying mostly on information exchange. Purchasing flood insurance, for example, is strongly influenced by higher assessed home values ($p<0.001$), long housing tenure ($p<0.01$), and receipt of information from the media (written and electronic) ($p<0.001$) and through personal connections ($p<0.05$). Location outside of the 100-year floodplain is also a significant predictor ($p<0.05$), most likely because FEMA mandates flood insurance for most homeowners living in the SFHA.

The decision to contact governmental agencies for information on flood hazards (Model 7) appears to be influenced by a different set of factors. For instance, home value has a negative effect ($p<0.001$) on the dependent variable: those living in more expensive homes are less likely to pursue this technique. Flood experience is also an important predictor, the only model where this variable is statistically significant ($p<0.01$). Residents living further away from the coastline are less likely to seek information from governmental agencies. Lastly, acquiring flood information from personal contacts significantly increases the likelihood ($p<0.001$) that a respondent will then contact agencies for more details.

The last household adjustment examined in the study, attending meetings to learn about flood hazards (Model 8), follows a similar statistical pattern in that distance from the coast reduces the likelihood ($p<0.001$) of a respondent pursuing this mitigation activity. Information stemming from personal relationships also increases the odds that a homeowner will attend meetings on flooding.

Overall, respondents engaging in the three information-based, non-structural flood adjustments are consistently influenced by communities with higher CRS scores. Respondents are approximately 1.5–2 times more likely to participate in these activities if the jurisdictions in which they live make a commitment to flood mitigation and public outreach efforts to inform better the public about flood risks.

Discussion

From the descriptive results, it appears that survey respondents favour flood mitigation techniques that: (i) necessitate the least amount of effort and expense; and/or (ii) are advocated or required by the local jurisdiction. For instance, purchasing federal flood insurance is a well-known, affordable, and ubiquitous method of protecting a household against future flood damage. For those respondents living within the FEMA-defined 100-year floodplain with a home mortgage, insurance is obligatory. Other popular behavioural techniques, such as storing valuable items on the second floor of a home, represent the most easily accomplished means of avoiding future flood-related losses, the 'low-hanging fruit' vis-à-vis mitigation techniques.

Logistic regression results add further insights into why a respondent would select a particular household adjustment. This study probed three categories of mitigation techniques—structural and expensive, behavioural with minor modifications, and purely informational—each with its own set of significant predictors. In general, it found that expensive solutions requiring extensive structural changes are driven by higher home values and longer housing tenure. As expected, respondents are more likely to invest in protecting homes of higher value (they are also likely to have more financial resources) to which they have an emotional attachment because they have been living in the structures for a long period of time—the significant correlation between assessed value and elevation in Table 3 exemplifies this relationship. Residents who are committed to staying in their homes are more likely to commit to the effort and expense compelled by structural techniques because they believe they will be more likely to see their investment pay off in the future. In contrast, residents living in their homes for a short amount of time (lower housing tenure) are generally more likely to rely to a greater extent on inexpensive techniques involving mostly behavioural modifications, such as wet-proofing and second-floor storage (shown by the significant correlation in Table 3). These people may not have formed an attachment to their home or be committed to living in it in the long term, so they may be less eager to invest in major renovations. Despite research to the contrary (Browne and Hoyt, 2000; Kreibich et al., 2011), this study finds that experience of flooding alone is not a major motivator of household adjustments to mitigate flood risk. In fact, the only protective behaviour sensitive to experience is contacting governmental agencies for flood information, leading us to agree with Lindell and Hwang (2008) that this independent variable probably has an indirect influence on household adjustments. The findings thus add to the theory of protective action in that experience has to be layered with length of contact, emotional attachment, and other factors to stimulate flood risk adjustments at the household level.

Another important result stemming from the logistic regression models is the influence of from where respondents receive their information on flood hazard risks. Aside from insurance, which usually is presented in written form or during legal transactions, respondents rely more on information obtained from friends and relatives and through personal interactions when selecting a flood hazard adjustment for their household—as also found by Kunreuther et al. (1978). This finding is important for public officials who tend to focus on written and electronic media outlets to disseminate hazard information to local residents. In contrast, receiving information from the media was not a major predictor of household adjustment, except for buying flood insurance. Jurisdictions interested in informing and influencing residents on household flood mitigation may instead want to concentrate more on face-to-face meetings, workshops, discussions, and other methods that facilitate personal interaction.

In jurisdictions with higher CRS scores, respondents are more likely to choose information-based mitigation techniques. This result was expected because the FEMA CRS programme focuses on non-structural community-level flood mitigation involving major engagement with local residents. Hence, flood insurance purchase, meeting attendance, and contact with public agencies are all significantly more prevalent in jurisdictions that make more of a commitment to informing the public of flood risk and mitigation opportunities. Residents in higher scoring CRS communities also receive two additional benefits: previous research suggests that homeowners experience significantly less flood damage (Brody et al., 2008; Brody and Highfield, 2013; Highfield and Brody, 2013); and residents living in communities with higher CRS scores receive a larger discount on their insurance premiums (up to 45 per cent).

Finally, variables measuring proximity to risk zones behave somewhat unexpectedly across the various household adjustments. Distance from the coastline and streams, in particular, has little effect on the way in which respondents select household mitigation techniques. These results support the notion that residents generally are not fully aware of their degree of flood risk and do not always use location factors to make household adjustment decisions, especially as compared to socioeconomic factors. The lack of awareness of geographic flood risk may be a critical factor in the amount of flood damage household incur over time (Zhang, Prater, and Lindell, 2004; Arlikatti et al., 2006).

One should also note that the risk perception variable behaved counter to assumptions pervading the scientific literature. We offer two explanations for the low statistical correlations between flood risk perception and household adjustments. First, respondents in this study who are informed about or aware of flood risks have previously made a decision to locate outside of flood zones or at higher elevations, negating the need to adopt household adjustments. For instance, more than one-half of the sample living outside of the 100-year floodplain reported a risk perception score above the median response (14 out of 30). Second, survey respondents as a whole are simply not aware of the actual flood risk to their properties, even though proximity plays a crucial part in determining the likelihood of flood damage to a property (Brody et al., 2012). This study pinpointed a disconnection between perceived and measurable risk (that is, the 100-year floodplain), which is important in explaining household adjustment to the threat of floods and risk assessment in general.

Conclusion

This study has analysed statistically the factors contributing to the adoption of various household flood hazard adjustments. The results will be of value to governments and decision-makers that want to encourage homeowners to take protective action in the face of increasing flood risk. As discussed above, motivating factors vary based on the type of household adjustment. While this is one of the few assessments to evaluate household-level flood mitigation activities while controlling for multiple socioeconomic, proximity, and perception-based variables, one should consider it to be only a first step towards investigating the topic. Future research should assess a larger number of jurisdictions over a wider geographical region. Larger samples would increase statistical power, as well as allow for additional socioeconomic and geographical items to be integrated into the models, which may provide further insights into mitigation behaviour. Second, future work should look at how the adoption of flood mitigation techniques changes over time based on shifting conditions and new events. Finally, the results indicate the importance of CRS initiatives in increasing the likelihood that residents will adopt information-based flood adjustments. Research should be done, too, on which specific CRS activities at the community level have the greatest impact on household decisions related to reducing flood loss.

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Endnotes

[1] See http://www.fema.gov/policy-claim-statistics-flood-insurance/policy-claim-statistics-flood-insurance/policy-claim-13 (last accessed on 26 July 2015).

[2] See https://www.fema.gov/national-flood-insurance-program (last accessed on 26 July 2016).

[3] See https://www.fema.gov/statistics-calendar-year/loss-dollars-paid-calendar-year (last accessed on 26 July 2016).

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