A Review of Community Flood Risk Management Studies in the United States

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Abstract

Given the substantial and diverse body of research on community flood risk management in the United States, there is a need to establish the current state of knowledge, synthesize the methodological dimensions of community flood risk management studies, and identify directions for future research on community flood risk management. The present study addresses these needs by conducting a comprehensive and systematic review of community flood risk management empirical studies in the United States. We searched three academic databases and identified 60 studies that met our selection criteria (e.g., study must be focused on flood risk management at the community level and conducted in the United States). Findings indicate that the number of studies on community flood risk management is increasing, most studies employ flood mitigation and flood impact as their dependent variables, the preferred analytical method is regression, and this literature is dominated by social scientists, among other findings. We discuss six themes that emerge, present four recommendations based on the gaps identified, and outline a robust research agenda for enhancing communities' resilience to future flood disasters.

Keywords: community flood risk management, flood policy, community rating system, flood risk, flood damage, flood loss

1. INTRODUCTION

Flooding remains the most destructive and costliest natural hazard in the United States (Cigler 2017; Noonan and Sadiq 2018). Over the past fifteen years, major flood events have constituted approximately 85 percent of all Presidential Disaster Declarations (Cigler 2017). Moreover, a recent report by the National Weather Service (NWS) indicates that the 30-year annual average for flood-related deaths and damages in the United States is 85 fatalities and $7.95 billion, respectively (National Weather Service 2017). The rising costs of floods is not peculiar to the United States. Between 1980 to 2013, the global direct economic losses from floods surpassed one trillion dollars and more than 220,000 individuals were killed from floods (Winsemius et al., 2015). The high costs associated with flood events stem from the interaction between the physical, built, social, and political environments. Persistent residential and commercial development along the United States coastline and floodplains has resulted in individuals and communities becoming more vulnerable to flood hazards (Brody *et al.* 2010). Furthermore, climate change impacts in terms of increased precipitation and rising sea levels exacerbate flood risks for both inland and coastal communities (Bouwer 2011)

Due to the regularity and severity of flood events, scholars from a variety of disciplines (e.g., economics, sociology, planning, public policy, engineering, environmental science) have paid substantial theoretical and empirical attention towards understanding how communities can better manage their flood risks. Communities are increasingly seen as an important unit for flood-risk-related decision making (Noonan and Sadiq 2019). In this study, the term "community" refers to a single or collection of counties and/or neighborhoods. Using counties and neighborhoods as the unit of observation is appropriate as local flood risk management decisions are made at both of these levels. For example, in some states, community flood risk management activities are primarily a function of city governments yet in others it is a primary function of the county government. Decisions to engage in structural (e.g., constructing dams and levees) and non-structural (e.g., regulating land use, purchasing flood insurance) mitigation measures as well as participate in flood risk management programs like the Federal Emergency Management Agency's (FEMA) Community Rating System (CRS) program is made at the community level (Brody et al., 2010). The CRS program is a voluntary program created in 1990 to incentivize communities to implement floodplain management activities that go beyond those required under the National Flood Insurance Program (NFIP). The incentive for participating in the program is that flood insurance policy holders in participating communities can receive reductions in their flood insurance premiums of up to 45 percent.

In recent years, researchers have explored how communities plan for flood events (Bailey 2017; Kang 2009) and the effect certain community-level flood mitigation strategies and policies have on flood losses (Brody *et al*. 2007a, 2007b, 2007c, 2008, 2011, 2012b, 2013a, 2013b, 2015a, 2015b, 2017; Burby and French 1981; Calil *et al.* 2015; Esnard *et al*. 2001; Grigg *et al.* 1999; Highfield *et al.* 2014; Highfield and Brody 2006; Holway and Burby 1993; Kousky and Walls 2014). Researchers have also examined new models and tools practitioners can employ to better manage community flood risks (Blessing *et al.* 2017; Brody *et al.* 2012a, Deegan 2007; Gall *et al.* 2007; Lathrop *et al*. 2014; Olsen 2014). More recently, scholars have begun to unpack the direct and indirect effects of the CRS program (Asche 2013; Fan and Davlasheridze 2014, 2015; Highfield and Brody 2013; Landry and Li 2011; Li 2012; Li and Landry 2018; Noonan and Sadiq 2018; Posey 2009; Sadiq and Noonan, 2015a, 2015b; Zahran *et al.* 2009, 2010).

Based on the substantial and diverse body of research on community flood risk management, there is a need to establish the current state of knowledge, synthesize relevant methodological dimensions, and identify research gaps in the current community flood risk management literature. The present study addresses these needs by presenting a comprehensive and systematic review of empirical community flood risk management studies done in the United States. More specifically, the purpose of the present study is to: (1) identify trends in the methodological dimensions of the community flood risk management literature such as research objectives, areas studied, analytical approaches, among other things; (2) synthesize major findings from the community flood risk management literature; and (3) identify areas for future inquiry. The main contribution of this literature review is the identification of the broad and distinct patterns among the 60 studies included in this review in terms of research topics, techniques, and data–patterns that cannot be observed by looking at any individual study. In doing so, this study identifies gaps in the community flood risk management literature and offers recommendations for addressing the gaps. This study also provides a foundation for theory building. Specifically, this review can serve as a good foundation to develop theories of community flood risk management that will lead to greater advancements in the field.

2. METHODS

2.1 Search Strategy and Selection Criteria

A systematic literature review refers to a thorough, methodical, and orderly approach for appraising articles for inclusion. This differs from a rapid or scoping review as such reviews are less rigorous and provide a preliminary assessment of available research (Grant and Booth 2009). A systematic approach allows scholars to reduce biases in article selection and ensure all relevant articles are included in the review. To identify studies for inclusion, we adopted a three-stage approach (see Figure 1).

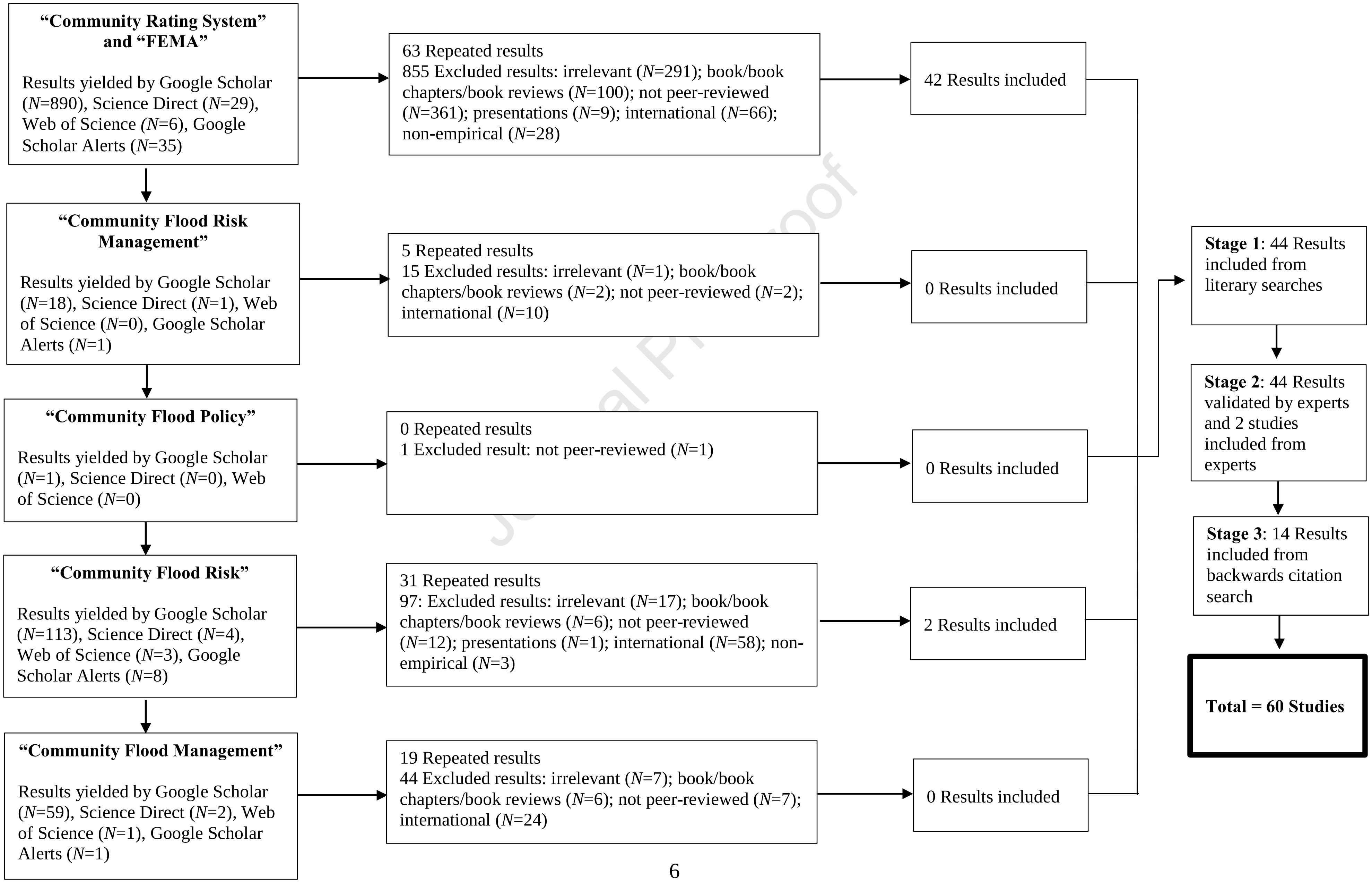

Fig. 1. Diagram of Studies Selected for Inclusion.

In the first stage, we searched papers indexed in three literary databases—Google Scholar, Science Direct, and Web of Science. This search strategy is common among researchers (Bubeck *et al.* 2012; Thompson *et al.* 2017). We began our literary search in May of 2017 using the search term "Community Rating System" and "FEMA." We started with this keyword search because we presumed that studies examining community flood risk management in the United States would reference—either in great detail or in passing—FEMA's CRS program. Altogether, this keyword search yielded 890 results from Google Scholar, 29 from Science Direct, and six from Web of Science. To identify additional studies, we searched the three literary databases using the following keywords: "community flood risk management," "community flood policy," "community flood risk," and "community flood management." After accounting for repeated results found both within the same keyword search as well as in prior keyword searches, these searches generated an additional 202 studies. Although we concluded our keyword searches on June 16, 2017, we used Google Scholar Alerts to include studies uploaded to Google Scholar that contained any of the pre-identified search terms up to December 31, 2017. These alerts provided us with 45 additional studies to review. In total, we screened 1,172 papers and reviewed 1,053 papers. Of these 1,053 papers reviewed, 44 matched the selection criteria.

Papers identified from the above search strategy are included in the review so long as they met the following selection criteria: (1) written in English; (2) focused on flood risk management at the community level; (3) examine the United States; (4) peer-reviewed journal article, conference paper, conference proceeding, or dissertation; (5) are empirical by relying on experience or observations (studies might use primary and/or secondary data as well as quantitative and/or qualitative data).

For organizational purposes, we developed a spreadsheet to track both included and excluded studies. For every paper generated by each keyword search, a researcher reviewed the title and abstract to determine if it met the criteria for inclusion. If it was determined the study met the criteria for inclusion, the researcher obtained a full-text version of the article. If the researcher determined the study did not meet the criteria, the researcher listed the study separately and coded the reason for exclusion such as not written in English, irrelevant, international (i.e., study does not focus on the U.S.), not peer-reviewed, non-empirical, book, book chapter, or book review, or presentation. If the researcher could not determine whether the paper should be included or excluded based on the title and abstract, the researcher obtained a full-text version of the article and examined it in greater detail before making the final eligibility determination.

We developed guidelines for selecting the reason for exclusion in cases where multiple reasons existed (e.g., the study is irrelevant, does not focus on the United States, and is non-empirical). Specifically, the first method for determining the reason for exclusion was to identify whether the study is written in English. The second method was to determine if the study is relevant, and the third step was to determine whether the study's focus is on the United States. The fourth and fifth steps were to ensure the study is peer-reviewed and empirical, respectively. Hence, if a study is irrelevant, does not focus on the United States, and is non-empirical, the researcher coded the article as irrelevant. We coded books, book chapters, and book reviews as well as presentations as just that regardless of if they are irrelevant, international, not peer-reviewed, or non-empirical.

In the second stage, we sent a list containing the initial 44 studies to six community flood risk management experts via e-mail to validate our list and to add any missing eligible studies.

These experts have published several studies on community flood risk management, are well cited in scholarly publications, and represent a wide range of disciplines—city and regional planning, sociology, urban and regional science, and economics. Altogether, these experts recommended 10 studies. We reviewed the 10 studies provided by the experts and determined that two of them matched the selection criteria.

The third and final stage involved carrying out a backwards citation search. This entailed going through the references of all 44 studies found in stage one and the two additional studies found in stage two. This process led to the discovery of 14 new studies that met the selection criteria. In total, 60 studies met the selection criteria and were included in the review.

It is important to recognize that the adopted strategy may have excluded some articles. For example, it is possible that we omitted some studies given the wide range of disciplines studying community flood risk management. It is also possible that including the word "community" in all the keywords may have tilted our sample towards social scientists and away from other disciplines that may not engage the term much, such as engineers and other non-social scientists. Nevertheless, our three-step search procedure—comprehensive search of the literary databases, validation of eligible studies by experts, and backward citation searches—reduces the likelihood that we missed any eligible study based on our eligibility criteria.

2.2 Article Review Strategy

Two of the authors reviewed the 60 studies included in the review and coded the methodological dimensions of each study, including, but not limited to, the authors' disciplines, research question, study area, sample size, dependent and independent variables, data sources, and analytical approach (Bubeck *et al.* 2012; Thompson *et al.* 2017). To ensure inter-coder reliability, these two individuals separately reviewed and coded the methodological dimensions of 10 randomly selected articles from the 60 articles eligible for the review. After reviewing and coding the 10 articles, these two individuals compared their codes and discovered only one discrepancy in codes, which was resolved by consensus. The remaining 50 studies were evenly distributed to the two authors and were coded individually. After the remaining studies were reviewed and coded, these two individuals met again to discuss any concerns and to validate certain codes. No additional issues were found.

3. METHODOLOGICAL DIMENSIONS

The 60 eligible studies exhibit a variety of methodological dimensions. Table A in the Appendix presents a condensed version of the methodological dimensions of the 60 studies included in the review.

3.1 Research Objectives

Research objectives are coded by first reviewing the research question(s) and purpose of each study and then by identifying commonalities among the 60 studies. Seven of the 60 studies included in this review primarily focus on understanding communities' flood risks. For example, studies examine the relationship between climate and societal factors that contribute to communities' level of flood damage (Pielke and Downton 2000) and the number of flood casualties (Zahran *et al.* 2008). Studies also explore the social and spatial inequities that result in increased flood risk exposure for certain sociodemographic groups (Chakraborty *et al.* 2014). Other studies explore the physical and institutional characteristics that influence communities' ability to adopt flood mitigation strategies (Brody *et al.* 2009, 2014; Consoer and Milman 2017; Mogollón *et al.* 2016).

In addition, a host of studies included in this review examine communities' efforts to plan for flood events (*N*=2) and how communities can best mitigate flood losses (*N*=20). For example, studies assess the effects of local plans on flood costs (Bailey 2017) and flood losses (Kang 2009). Studies also explore the relationship between the adoption of flood mitigation strategies and property damage (Highfield *et al.* 2014) as well as overall flood losses (Holway and Burby 1993). Finally, several studies look at the effects of land-use on flood losses (Brody *et al.* 2007c, 2017; Burby and French 1981) and the role wetlands play in reducing flood damages (Brody *et al.* 2007a, 2007b, 2007c, 2015a, 2015b; Highfield and Brody 2006). Some studies also explore how certain community development patterns can either reduce or exacerbate flood losses (Brody *et al.* 2011, 2013a, 2014; Esnard *et al*. 2001).

Sixteen of the 60 studies included in this review focus on a specific flood mitigation program—FEMA's CRS program. Recall, FEMA's CRS program is a voluntary program designed to incentivize communities to implement floodplain management activities that surpass those required under the NFIP. In exchange for adopting additional flood mitigation measures, flood insurance policy holders in participating communities enjoy reductions in their flood insurance premiums commensurate with their number of credit points. Credit points are awarded based on a community's ability to implement any of the 19 creditable activities that span across one of four categories: public information, mapping and regulations, flood damage reduction, and warning and response (FEMA 2017). These 15 studies look at various aspects of the CRS program including the determinants of participation (Asche 2013; Landry and Li 2011; Li 2012; Li and Landry 2018; Sadiq and Noonan 2015b), the program's non-linear incentive structure (Zahran *et al.* 2010), adaptive capacity (Posey, 2009), and policy learning (Brody *et al.* 2009a). Others investigate the CRS activities that result in the greatest reduction in flood losses

(Highfield and Brody 2013) as well as the CRS activities that are valued the most (Fan and Davlasheridze 2014). Finally, a few studies examine the effects the CRS program has on insured flood losses (Highfield and Brody 2017), residential choices (Fan and Davlasheridze 2015; Zahran *et al.* 2010), and poverty and income inequality (Noonan and Sadiq 2018).

Six studies included in this review look at existing models or tools or have developed new models and tools practitioners can employ to better manage flood risks (Blessing *et al.* 2017; Brody *et al.* 2012a, Deegan 2007; Gall *et al.* 2007; Kousky and Walls 2014; Lathrop *et al.* 2014; Berke *et al.* 2014). For example, studies explore workarounds for when digital flood data and maps are unavailable (Deegan 2007) as well as the extent to which the 100-year floodplain is a sufficient marker for delineating flood risks and predicting flood damage (Blessing *et al.* 2017; Brody *et al.* 2012a; Patterson and Doyle 2009). Studies also examine how geospatial decision-making tools could be developed and improved to promote coastal resilience (Lathrop *et al.* 2014) and tested the effectiveness of a stakeholder-built decision-support system to communicate flood risks (Olsen 2014).

Finally, nine studies assess perceptions and responses to flood events and flood policies. For example, one study examines the extent to which perceptions of flooding differ across stakeholders (Albright and Crow 2015b) while another explores how learning processes and stakeholder participation vary across communities in response to extreme flood events (Albright and Crow 2015a). Additional studies consider how flood policies impact mitigation outcomes (Berke *et al.* 2014; Deegan 2007; Kick *et al.* 2011; Paul and Milman 2017).

3.2 Study Area, and Inland vs Coastal

Study area is coded by determining the geographical scope of each study (e.g., national, regional, state, and local). Of the 60 studies included in this review, 12 examine community flood risk management at the national level (i.e., in the United States as a whole). Other studies look at community flood risks within an entire state whereas a higher number of studies examine specific towns, counties, and geographical regions within a state. The present study focuses on the specific state where each study was conducted. Fig. 2 shows a map of the distribution of studies by state. Many of the studies were conducted in Texas (*N*=7), Florida (*N*=7), or both (*N*=4). Additional studies examine other coastal states such as North Carolina (*N*=5*)*, New Jersey (*N*=2), South Carolina (*N*=1), New York (*N*=1), Massachusetts (*N*=1), California (*N*=1), or a combination of coastal states (*N*=9). A small portion of the included studies examine inland states such as Colorado (*N=3*), Missouri (*N=2*), Pennsylvania (*N*=1), and Vermont (*N*=1). Two studies examine a small group of both inland and coastal states, while one study did not specify its geographic scope.

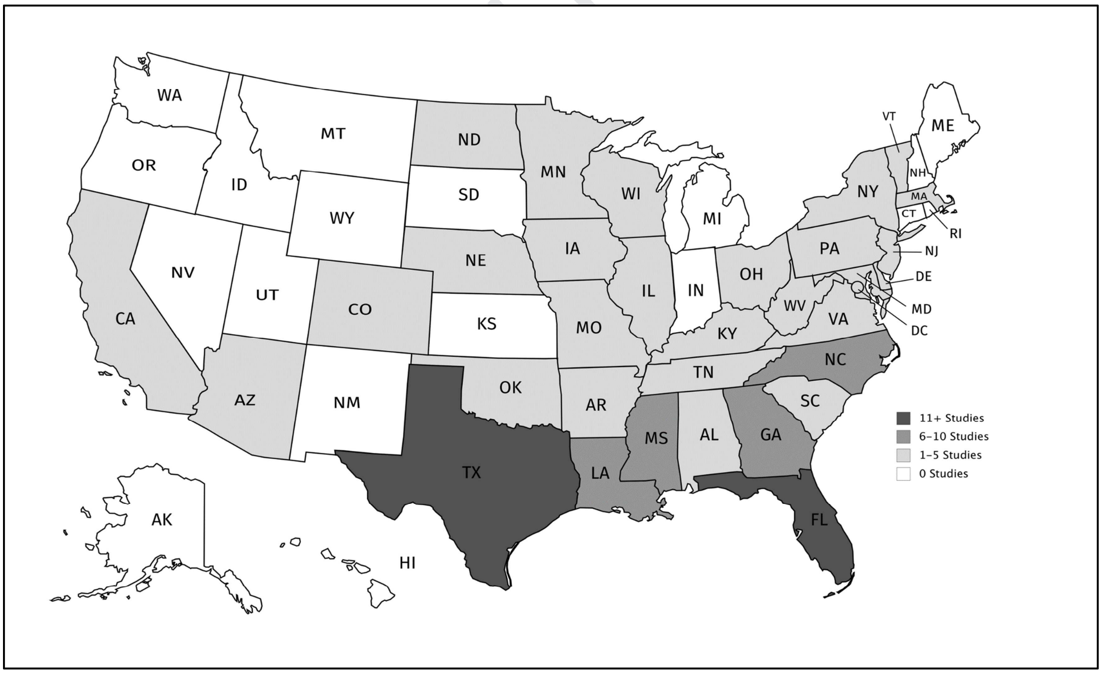

Fig. 2. Map Showing the Distribution of Studies by State.

We dig deeper into the study area variable by identifying whether a particular study focuses on coastal areas, inland areas, or both. Of the 60 studies included in this review, 20 examine coastal areas, six focus on inland areas, and 32 examine both coastal and inland areas. Two studies do not explicitly specify whether their study observe coastal or inland areas.

3.3 Timing of Assessment and Year of Publication

Timing of assessment is first coded as panel or cross-sectional and then as the year(s) under observation. A large portion of the included studies examine community flood risk management over multiple periods of time (*N*=36); time periods range from 65 years (Pielke and Downton 2000) to four years (Brody *et al.* 2012b). Seventeen of the 60 studies included in this review are cross-sectional, and seven studies do not report the exact timing of their assessments. We also code the year in which each study was published. All of the studies included in this review were published between 1976 and 2017, with the exception of one study that was forthcoming at the time of analysis (e.g., Li and Landry 2018). Fig. 3 shows the distribution of the 60 studies during the study period. In general, this graph indicates a positive trend in the number of studies on community flood risk management. For example, prior to 2000, researchers published only five studies. In contrast, 30 (50 percent) of the studies included in this review were published between 2013 and 2017.

3.4 Type of Study, Data Type, and Data Sources

Type of study is coded as quantitative, qualitative, or both. Fig. 3 shows the number of studies using primary data, secondary data, or both. Of the 60 studies reviewed, there are significantly more quantitative studies (*N*=54) than qualitative studies (*N*=2). It is important to note that the only two qualitative studies were conducted in 2017. In addition, four studies are both quantitative and qualitative. We also recorded the data type by whether a study uses primary or secondary data. Most of the studies (*N*=47) included in this review analyze secondary data. Five studies analyze primary data and eight studies analyze both. In terms of data sources, several studies obtained secondary data from FEMA, United States Census Bureau, Spatial Hazard Events and Losses Database (SHELDUS), National Climate Data Center, city and county government offices, among others.

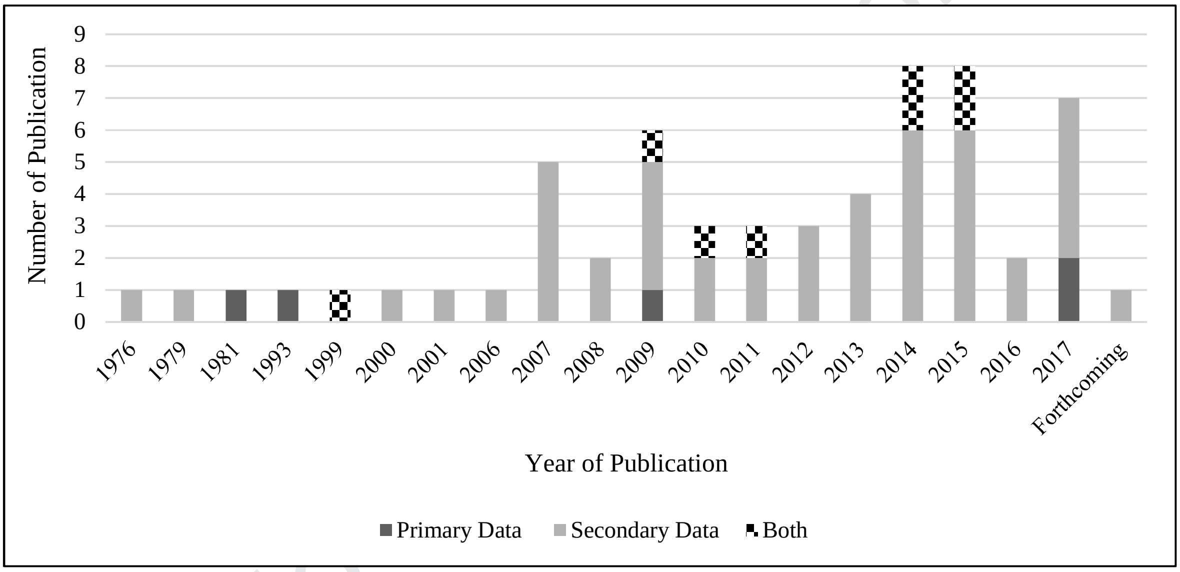

Fig. 3. Number of Studies using Primary Data, Secondary Data, or Both during the Study Period (*N*=60).

3.5 Unit of Analysis and Sample Size

We code the unit of analysis by identifying the geographical unit of each study such as the community, state, etc. This is different from the unit of observation, which refers to the level at which data is collected. Hence, in some cases, the unit of analysis and unit of observation are the same whereas in others they are different. The unit of analysis is the higher level of aggregation. Most of the studies *(N=*24*)* examine flood risk management at the neighborhood level, which includes cities, towns, villages, jurisdictions, municipalities, local governments, as well as

Census tracts and places. Twenty-two studies examine flood risks at the county/parish level. In addition, five studies examine flood risk management at the watershed level, three at the property/parcel level, two at the regional level, one at the national level, one at the individual level, one at the household level, and one at the property, catchment, and community level. We also record the sample size—the number of observations reported by the studies—for all 60 studies (see Table A in the Appendix). The sample sizes vary significantly across the 60 studies, from one (Grigg *et al.* 1999) to 1.8 million (Fan and Davlasheridze 2015). The average sample size is 21,874. For studies with multiple sample sizes, we use the average of their sample sizes.

3.6 Variables and Analytical Approach

We also code the dependent and independent variables for each study. As illustrated in Table A, several studies have multiple independent variables and a handful of studies include more than one dependent variable. To understand the current state of research on community flood risk management, we analyze the dependent variables further. We assess how the dependent variables varied over time by recoding the dependent variable(s) for each study into one of the following five categories: flood mitigation, flood impact, flood risk, socioeconomic characteristics, or other. As indicated in Fig. 4, many studies employed flood mitigation (*N*=22) or flood impact (*N=21*) as the dependent variables. These two research emphases have remained relatively stable over the study period. The sample size is greater than the number of studies because four studies had multiple dependent variables.

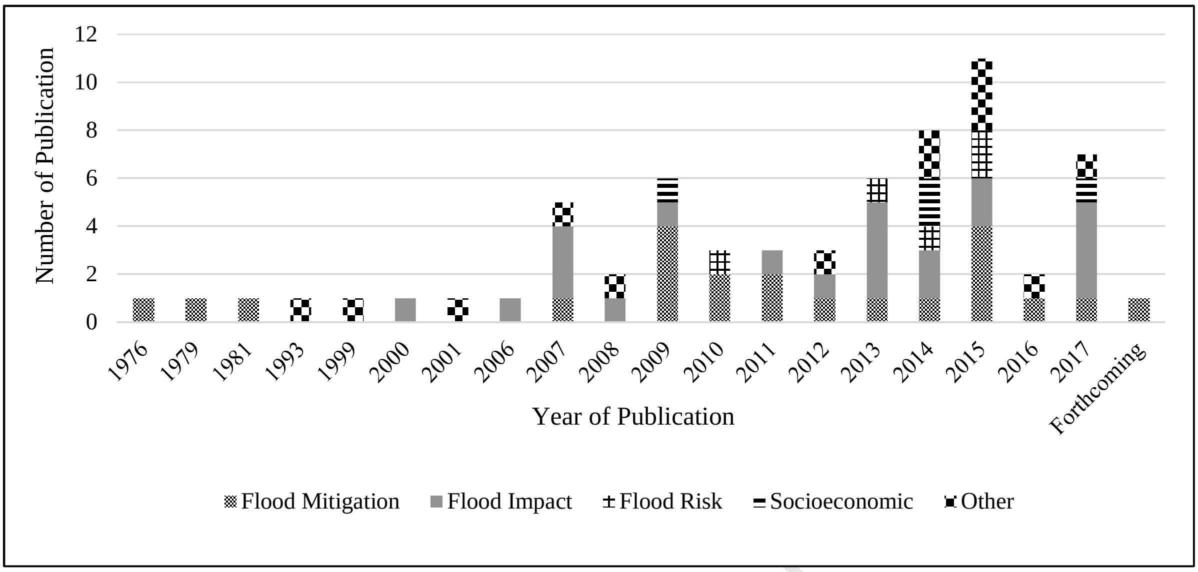

Fig. 4. Dependent Variables Studied (*N*=65).

The 60 studies included in this review employ different types of analytical approaches. We categorize the analytical approaches into six groups—univariate/bivariate analysis, regression analysis, multiple equation models, spatial analysis, any combinations of the previous four, and qualitative analysis (see Table 1). Many of the studies (*N*=32) use regression analysis (e.g., Ordinary Least Square regression, panel corrected linear regression, fixed-effects regression, and regression discontinuity). Qualitative analysis techniques are the least utilized (*N*=4), and when they are used, they often rely on qualitative analytical tools such as NVivo (Albright and Crow 2015a; Paul and Milman 2017).

Table 1. Number of Analytical Techniques Used During the Study Period (*N*=60)

Year of Publication	Univariate/ Bivariate	Regression	Multiple Equation Model	Spatial Analysis	Combination	Qualitative
1976	0	0	0	0	1	0
1979	0	1	0	0	0	0
1981	1	0	0	0	0	0
1993	0	1	0	0	0	0
1999	1	0	0	0	0	0

2000	0	0	0	0	1	0
2001	0	0	0	1	0	0
2006	0	0	0	0	1	0
2007	0	3	1	1	0	0
2008	0	1	0	1	0	0
2009	2	3	0	0	1	0
2010	0	1	0	0	1	1
2011	0	2	1	0	0	0
2012	0	2	0	0	1	0
2013	0	4	0	0	0	0
2014	0	4	2	1	1	0
2015	0	4	1	1	1	1
2016	0	1	0	0	1	0
2017	1	4	0	0	0	2
Forthcoming	0	1	0	0	0	0
Total	**5**	**32**	**5**	**5**	**9**	**4**

3.7 Author Discipline

For the author discipline, we code the studies according to the major discipline an author's highest degree was in. We use the following five major disciplines—social science, natural science, physical science, engineering, and law. We also create a category for multidisciplinary and other. Multidisciplinary refers to authors that had their highest degree in multiple disciplines (e.g., engineering and environmental science). Three studies belong to the category "other" and were not included in this analysis. The category "other" includes authors that are considered support staff (e.g., GIS coordinator). For each of the authors, we assign a publication. For instance, a publication with five authors is counted five times. This is why the sample size is much higher (N=163) than the number of studies (N=60). Based on Fig. 5, there is a rise in the number of authors per study over time (year and author number are correlated at ρ=0.28, p=0.034). With regards to the disciplines engaging in community flood risk management, it is quite clear that social scientists have the highest number of studies with 126 publications. This number is higher than that for all the other categories combined. Furthermore, 53 out of the 57 studies have at least one social scientist among the coauthors, and 35 of the 57 studies are authored exclusively by social scientists. Natural scientists occupy the second position with 21 publications, while physical scientists have no publication. Despite the preponderance of studies by social scientists, it is worth noting that studies with social scientists only are becoming less common in recent years (ρ=-0.25, p=0.062).

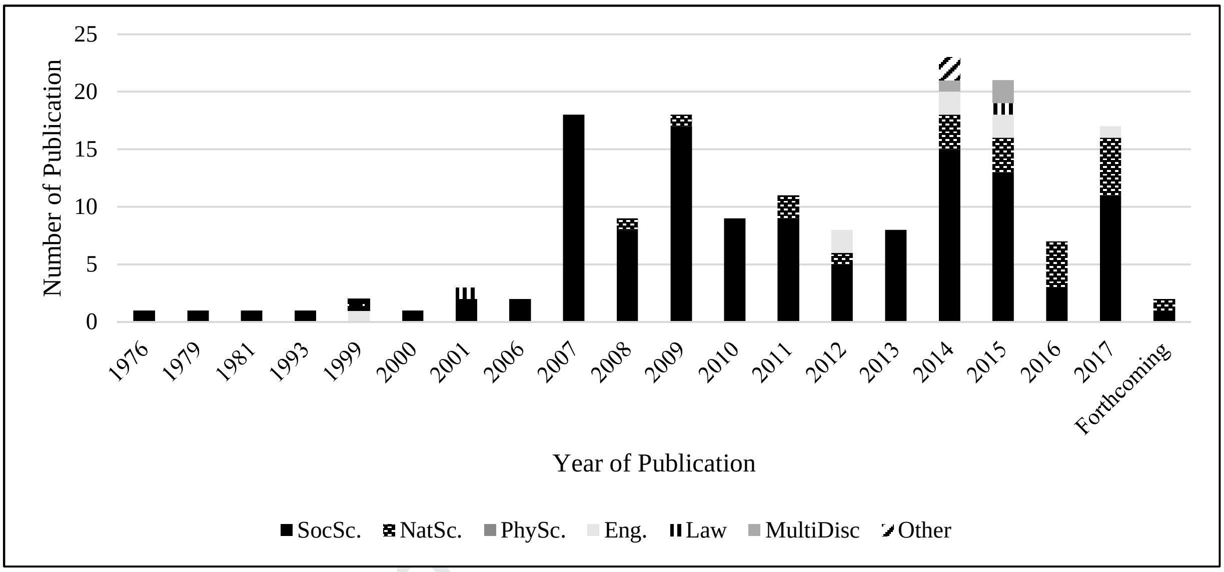

Fig. 5. Author Discipline by Year (*N*=163).

Table 2 shows the number and types of analytical approaches used by the major disciplines. Regression analysis is by far the most favored analytical approach for all the major disciplines except for law, which prefers spatial analysis. It is noteworthy that no analytical approach is used by all the major disciplines.

Table 2. Analytical Approach Used by Disciplines (*N*=163)

Analytical Approach	**Social Science**	**Natural Science**	**Physical Science**	**Engineering**	**Law**	**Multidisciplinary**	**Other**
Univariate or Bivariate Analysis	9	1	0	2	0	0	0
Regression Analysis	80	6	0	4	0	2	0

Multiple Equation Models	9	2	0	0	0	0	0
Spatial Analysis	11	4	0	0	2	0	0
Combination of the Previous Four Approaches	14	5	0	2	0	0	2
Qualitative Techniques	4	3	0	0	0	1	0
Total	**127**	**21**	**0**	**8**	**2**	**3**	**2**

4. EMERGENT THEMES FROM THE LITERATURE

In addition to examining the methodological dimensions of the 60 studies, we organize the major findings from each study into six themes so we can provide a bird's eye view of the state of knowledge on community flood risk management. The themes were developed based on the authors' perceptions and understanding of each study. Specifically, to identify the themes, we first look at each of the 60 studies' research question(s) and major findings. Then, we group studies with similar or related research questions and findings together. Finally, we examine each of the groupings to determine the theme that is common among them. For example, studies that focus on the CRS program are grouped together and assigned the theme, FEMA's CRS Program. In total, we are able to identify six themes: understanding communities' flood risks (N=7), planning for flood events (N=2), reducing communities' flood losses (N=20), FEMA's CRS program (N=15), flood mitigation tools (N=6), and perceptions and responses to flood events and policies (N=10). Fig. 6 shows the number of studies included in each theme by year. The theme with the most frequency is reducing flood risk (N=20) followed by FEMA's CRS program (N=15). Planning for flood events has the lowest frequency (N=2). As the number of publications is increasing, so is the number of themes, with the highest number of themes (N=8) occurring in 2014 and 2015.

After examining time trends in the themes of these papers, two important patterns emerge. First, the share of studies dealing with the CRS and with planning for flood risk is growing over time (ρ=0.26, p=0.056). Conversely, the share of studies focusing on perceptions of flood risks and responses to flood events and policy is declining (ρ=-0.23, p=0.088). Second, the other research themes (i.e., understanding flood risk, reducing flood risk, flood mitigation methods and tools) continue to be studied without a significant time trend.

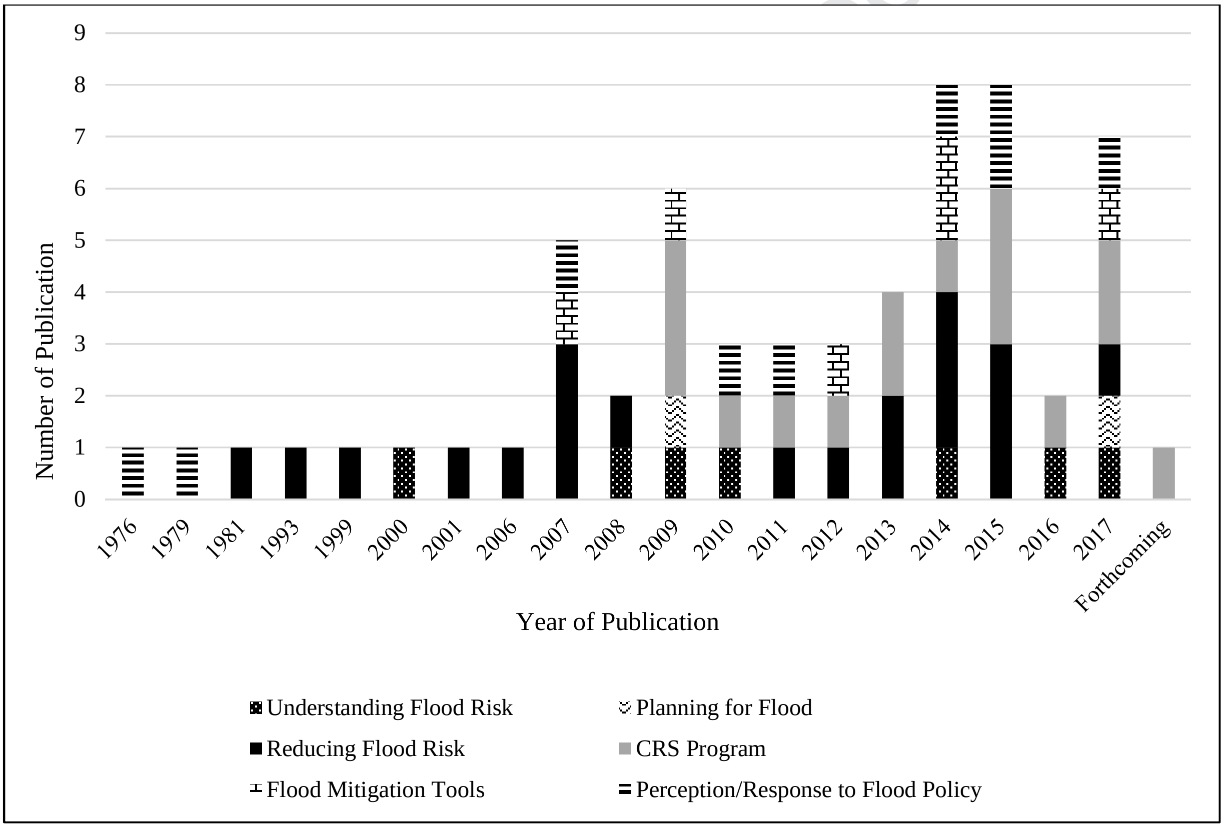

Fig. 6. Theme Trend during the Study Period (*N*=60).

4.1 Understanding Communities' Flood Risks

Studies included under this theme indicate that societal, physical, and institutional factors contribute to a community's flood risk. With regards to societal factors, studies demonstrate that sociodemographic characteristics matter when predicting communities' exposure to flood risks. For example, Chakraborty *et al*. (2014) employ an environmental justice approach to assess flood risk in Miami, Florida and find that flood risk differs by sociodemographic groups across flood zone categories. The authors specifically find that Black and Hispanic residents are significantly overrepresented in inland flood zones and underrepresented in coastal flood zones with significantly higher income levels and housing values (Chakraborty *et al.* 2014). Relatedly, Zahran *et al*. (2008) examine whether localities characterized as having higher percentages of socially vulnerable populations experience significantly more flood casualties. These authors find that the odds of a flood casualty increase with higher percentages of socially vulnerable populations as well as the level of precipitation on the day of a flood event, flood duration, property damage caused by the flood, and population density. In terms of physical factors, Mogollón *et al*. (2016) assess the effects of flow-regulating features on flooding and find that landscape features affect the magnitude and duration of floods with return periods (i.e., the likelihood of a flood event) less than or equal to 10 years, thus indicating that larger floods cannot be managed by solely manipulating landscape structure. Finally, concerning institutional factors, studies indicate that the capacity of organizations influences the ability of a community to adopt flood mitigation measures. Brody *et al*. (2009b, 2010), for example, find that organizational capacity is a significant factor contributing to the implementation of both structural and non-structural flood mitigation techniques., Consoer and Milman (2017) find that institutional factors drive municipalities to prioritize structural and non-structural mitigation measures and that the implementation of these measures is often hindered by state and federal regulations and by barriers to accessing funding from state and federal mitigation grant programs (e.g., FEMA's Hazard Mitigation Grant Program). Consequently, municipalities that engage in reactionary and ancillary flood mitigation measures typically remain vulnerable to flood disasters over time (Mogollón *et al.* 2016).

4.2 Planning for Flood Events

The two studies examining community-level planning for flood events indicate that the development and quality of mitigation plans have little effect on flood losses (Bailey, 2017; Kang, 2009). Bailey (2017), for example, finds that counties with mitigation plans experience higher flood costs in comparison to counties without plans. Moreover, Kang (2009) finds that plan quality had little effect on reducing insured flood damage, even after controlling for biophysical, built environment, and socio-economic variables. A possible explanation for these findings is that while communities with higher flood risks and more frequent disasters tend to develop better mitigation plans and implement additional hazard mitigation policies, these policies often lead to increased development in flood risk areas, which in turn, limits the effectiveness of mitigation plans (Kang 2009). Another possible explanation relates to implementation; communities may develop a flood mitigation plan, but may not follow through with implementing the strategies set forth in the document (Kang 2009).

4.3 Reducing Communities' Flood Losses

Studies included under this theme indicate that there are specific structural and non-structural mitigation strategies that are most effective at reducing communities' flood losses. For example, concerning structural mitigation strategies, a handful of studies suggest that acquiring and conserving open spaces significantly reduces the amount of property damage caused by flood events (Brody *et al.* 2013b, 2014, 2017: Calil *et al.* 2015). Moreover, a few of studies included in this review show that naturally-occurring wetlands are an effective flood mitigation tool and that the alteration of naturally-occurring wetlands results in increased flood losses (Brody *et al.* 2007a, 2007b, 2007c, 2015b; Highfield and Brody 2006). In terms of non-structural mitigation measures, Holway and Burby (1993) argue that elevating buildings to the NFIP standard is an effective strategy for reducing flood losses. Additional studies included under this theme demonstrate that specific development patterns can help stem flood losses (Brody *et al*. 2011, 2012b, 2013a, 2015a; Esnard *et al.* 2001; Kousky and Walls 2014). Brody *et al*. 2011, 2013a), for example, examine the influence of development patterns on flood losses along the Gulf Coast and find that clustered, high-intensity development patterns significantly reduce the amount of reported property damage. Finally, a few studies included under this theme more broadly assess a variety of flood mitigation strategies that are effective at reducing flood losses. Highfield *et al*. (2014) find that several mitigation activities (e.g., public outreach, mapping, and regulations) adopted at the community level result in significant savings in property damage for homeowners. Furthermore, Grigg *et al*.'s (1999) case study of the 1997 Fort Collins flood affirms the value of mitigation, a functional storm drainage program, and preparation for emergency response.

4.4 FEMA's CRS Program

Studies assessing the CRS program provide insights on various aspects of the program, including the determinants of participation, the effectiveness of the program in terms of reducing flood losses, and some of the program's unintended consequences. In regards to the determinants of participation, studies suggest—either in full or in part—that local capacity, flood-risk, socio-economic characteristics, and political-economy factors are significant predictors of initial and continuing CRS participation (Ashce 2013, Landry and Li 2011; Li 2012; Li 2012; Li and Landry 2018; Sadiq and Noonan 2015a 2015b; Paille *et al.* 2016). Studies also suggest that communities respond to the nonlinear, tiered incentives in the CRS program (Li 2012; Sadiq and

Noonan 2015a). For example, localities are motivated by the easy gains embedded in the CRS program, thus, suggesting that CRS localities behave strategically (Sadiq and Noonan 2015a; Zahran *et al.* 2010). Additional studies provide substantial support for the effectiveness of the CRS program in terms of reducing flood costs and damages. Highfield and Brody (2017) find that the CRS program has a statistically significant effect on reducing the amount of insured flood losses across the U.S. These authors also find that the following three CRS activities result in the greatest reduction in flood damages—freeboard requirements, open space protection, and flood protection (Highfield and Brody 2013). Finally, Noonan and Sadiq (2018) investigate the unintended consequences of the program by examining the relationship between the CRS and poverty and inequality. The results indicate that the CRS discourages income inequality in floodplains and that the CRS attracts poor residents, but relocates them away from floodplains (Noonan and Sadiq 2018).

4.5 Flood Models and Tools

Developing and using flood models and tools to manage flood risks represents another common theme among the 60 studies. A handful of studies under this theme provide evidence that the 100-year floodplain may not be an accurate illustration of flood risks (Brody *et al.* 2012a; Berke *et al.* 2014). Indeed, Brody and colleagues suggest that the 100-year floodplain may not be a sufficient marker for delineating flood risk and predicting property damage caused by flood events affecting coastal watersheds. Moreover, Patterson and Doyle (2009) assess the spatial changes inside and adjacent to the 100-year floodplain and find that there was a significant increase in flood exposure immediately outside the 100-year floodplain in North Carolina. In response to these studies, Blessing, Sebastian, and Brody (2017) seek to determine how to improve floodplain delineation and find that spatially distributed hydrologic models like *Vflo* can improve current methods for flood risk delineation, including FEMA's 100-year floodplain. Relatedly, Gall *et al*. (2007) explore alternative options for when digital flood data and maps are unavailable. Their analyses reveal that software programs like FEMA's Hazard United States-Multi-Hazard (HAZUS-MH) and the United States Geological Survey's Stream Flow Model 3.3 (SFM 3.3) are appropriate workarounds whenever digital flood data are missing or unavailable (Gall *et al.* 2007). Two studies included under this theme demonstrate that decision-making tools such as GIS can help promote community resilience and reduce flood risks (Gall *et al*. 2007; Lathrop *et al*. 2014) For example, Lathrop *et al*. (2014) assess New Jersey's GIS tool, *NJFloodMapper* and find that this tool can provide critical information on coastal flooding exposure and flood risks. Similarly, Olsen (2014) tests the effectiveness of a stakeholder-built decision-support system to communicate flood risks and find that this system performed well in communicating knowledge of flood risk, resulting in significant learning outcomes.

4.6 Perceptions and Responses to Flood Events and Policies

The studies included under this theme provide a better understanding of how communities and individuals perceive and respond to major flood events. With regards to perceptions of flood events, Albright and Crowe (2015a) examine how communities actively engage the public and other relevant stakeholders in decision-making processes in the aftermath of an extreme flood event. The authors find, among other results, that who participates in flood recovery processes influences how flood risks are perceived at the community level. In a related study, Albright and Crowe (2015b) explore the depth of stakeholder participation in the aftermath of the 2013 Colorado Floods and find that communities that have suffered damage across many sectors and have limited financial capacity are more likely to have motivated residents and interested organizations participate in flood recovery and planning processes. Concerning community-scale responses to flood events, research demonstrates that patterns and capabilities developed in the community through community actions not only influence communities' responsiveness to flood disasters (Lufoff and Wilkinson 1979) but also their participation in the federal flood insurance program (Moore and Cantrell 1976). Finally, additional studies included under this theme consider how flood policy affects mitigation (Deegan 2007; Berke *et al.* 2014; Kick *et al.* 2011; Paul and Milman, 2017). These studies differ from those included under the earlier theme 'reducing communities' flood losses' by employing mitigation as the outcome variable rather than flood losses. This line of research suggests that state policies as opposed to federal policies exert a greater effect on communities' decisions to adopt mitigation measures (Berke *et al.* 2014). Moreover, Kick *et al*. (2011) find that flood victims engage in less mitigation when there is a lack of trust between local flood management officials and flood victims and when flood victims perceive local flood management official to be unhelpful during the recovery to a flood event.

5. DISCUSSION

Due to the frequency and severity of flood events in recent years, scholars have paid substantial theoretical and empirical attention towards understanding how communities in the United States can better manage their flood risks. The present study systematically identifies these studies and synthesizes their findings. First, we analyze the 60 studies reviewed according to eight methodological dimensions: research objectives; study area, and inland vs coastal; timing of assessment and year of publication; type of study, data type, and data sources; unit of analysis and sample size; variables; analytical approach; and author discipline. Regarding the research objectives, the topic explored the most relates to how to mitigate flood risk, while the least attention has been paid to planning for flood events. Texas and Florida are the two states with the most studies. This is not surprising given that Texas has the highest flood-related fatalities in the United States (Zahran *et al.* 2008), and Florida is routinely affected by major hurricanes that lead to significant flooding (Brody *et al.* 2007a). A significant number of the studies examine coastal areas relative to inland areas. This result is not surprising considering the vulnerabilities of coastal communities to flooding. Timing of assessment result indicates that a majority of the studies examined multiple years in comparison to studies that looked at one year. Regarding the year of publication, the trend shows an increase in the publication of community flood risk management studies, especially from 2013 to 2017. This finding is particularly important as it suggests that more attention is paid to this topic. Increased attention to community flood risk management is a necessary step in combating the predicted increases in climate change impacts (Bouwer 2011). Results also indicate that there are significantly more studies using quantitative data relative to qualitative data, as well as using more secondary data than primary data. In addition, government agencies constitute the majority of data sources. Looking at the unit of analysis and sample size, the results show that studies are mostly conducted at the community (e.g., cities) and county levels, and there is a wide variation in sample sizes. Regarding the dependent variable of choice, the analysis indicates that most of the studies use flood mitigation or flood impact as their dependent variables. Finally, the results show that the preferred analytical approach is regression analysis, and social scientists have the highest number of community flood risk management publications. This latter result may be due to the selection criteria used to identify the studies (i.e., other disciplines may be more represented in studies *for* rather than *about* community flood risk management).1

[1] This is a key point in distinguishing this literature on community flood risk management from a much larger literature that might inform or be used by community flood risk management. A few examples, not selected for inclusion in our study, but could contribute to community flood risk management, help illustrate this distinction. A study modeling streamflows, like Todorovic and Zelenhasic (1970), addresses an important topic in managing flood

Second, we organize the findings from each of the 60 studies by themes to provide an overview of the state of the art on community flood risk management, identify research gaps, and offer recommendations in terms of areas in need of further investigation. By examining the research questions and major findings, we identify six themes. Theme 1: Understanding Communities' Flood Risk. A number of studies included in this review reveal that societal, physical, and institutional factors contribute to a community's flood risk (Brody *et al.* 2009b, 2010; Chakraborty *et al.* 2014; Conser and Milman 2017; Mogollón et al. 2016; Zahran *et al.* 2008). Theme 2: Planning for Flood Events. Somewhat surprisingly, studies that examine community-level planning for flood events demonstrate that the development and quality of mitigation plans has little effect on flood losses (Bailey 2017; Kang 2009). The lesson here is that those in charge of managing flood risks (e.g., emergency managers, floodplain managers) should not forego the development of hazard mitigation plans and policies, but should consider the extent to which they have implemented these plans as well as the extent to which these plans and policies might promote development in flood risk areas (Kang 2009). Theme 3: Reducing Communities' Flood Losses. Several studies included in this review examine how communities can reduce their flood losses. In general, these studies show that acquiring and conserving open space (Brody *et al.* 2014, 2017; Brody and Highfield 2013b; Calil *et al.* 2015), protecting naturally-occurring wetlands (Brody *et al.* 2007a, 2007b, 2007c, 2015b; Highfield and Brody 2006), and as long as development is situated away from flood-prone areas, clustered, high-intensity development patterns significantly reduce flood losses (Brody *et al.* 2011, 2013a). Theme 4: FEMA's CRS Program. A handful of studies indicate that participation in FEMA's

risk, but is excluded because of a lack of focus on the community. Similarly, Hall *et al*. (2013) model water flows over the landscape, useful information for flood managers and policymakers, but not a study about the community. Likewise, tools to evaluate the performance of flood defense measures (e.g., Simm *et al.* 2008) can be useful for flood risk management, but do not focus on the community. Even more holistic approaches, such as Fratini *et al*. (2012) can enhance decision-making, but the emphasis is not on the community.

CRS program is indeed an effective strategy for reducing community-level flood losses (Highfield and Brody 2013, 2017). Highfield and Brody (2013) specifically found that three CRS activities result in the greatest reduction in flood damages—freeboard requirements, open space protection, and flood protection. Theme 5: Flood Models and Tools. A few studies indicated that current flood risk tools such as the delineation of the 100-year floodplain may not be sufficient for measuring community flood risks (Blessing *et al.* 2017; Brody *et al.* 2012a, Patterson and Doyle 2009). This suggests that floodplain managers should consider alternative methods like spatially distributed hydrological models when delineating flood risks (Blessing *et al.* 2017). Theme 6: Perceptions and Responses to Flood Events and Policies: Several studies included in this systematic review demonstrate the importance of stakeholder engagement in flood recovery processes (Albright and Crow 2015a, 2015b) and show how state and federal policies impact mitigation (Berke *et al.* 2014; Deegan 2007; Kick *et al*. 2011; Paul and Milman 2017). Third, we conduct several multivariate analyses to identify significant patterns and tendencies in this literature. Unsurprisingly, the analytic techniques employed by researchers are not distributed independently across the different research themes (see Figure 6) ($\chi2 = 41.99$, $p=0.018$). For instance, all the papers using only spatial analyses are studies of reducing community flood risks, and we find no papers using regression techniques to study flood modeling and tools. Just as some techniques might naturally be better suited to some research theme more than others, we also see strong interdependence in the choice of research theme and the nature of the data. Furthermore, the unit of analysis is not independent of the research theme ($\chi2 = 62.52$, $p=0.013$). For example, studies with the theme of reducing communities' flood risks are more likely to analyze watershed-level units.

More distinct patterns emerge when we examine how the geographic scope of analysis (e.g., local vs. national studies) varies across research themes. Some of these patterns are to be expected, such as the tendency for studies of mitigation models and tools to apply at more local geographic scopes. Yet, some tendencies such as studies with a regional scope being disproportionately represented among studies on reducing communities' flood risks, may be less expected. While CRS studies appear disproportionately represented among state and national studies, there are fewer studies of CRS and planning for disaster events for local areas. This suggests a gap in the literature where thick description and richer, more detailed analyses of specific communities' experiences with CRS and flood event planning may be lacking. Obtaining data on local decision-making and detailed context may pose greater data collection costs than relying on publicly available secondary data, and it might also require more social scientists to engage more with planners and engineers in field research. Yet, these sorts of instigations may be important next steps to advancing our understanding of communities' risk-related decision-making. Studies of perceptions and responses to flood events and policies are disproportionately represented among the local studies and lack any coverage at the broader, national geographic scope. Without larger-scope (e.g., national) studies, comparative analyses will be limited. It will be difficult to know how key relationships concerning perceptions and responses vary from one region to another (e.g., riparian flood risk vs. coastal flood risk). Heterogeneity in risk landscape, and how communities perceive and approach their risks, is not well accounted for in the literature. In sum, this literature tends to cover some types of analyses far more than others, which both reflects the areas of greatest interest to researchers and points to areas receiving less attention.

This systematic and comprehensive review of the community flood risk management literature provides an opportunity to render a few recommendations for future research in this area. We identify and discuss four areas that could benefit from additional inquiries. We select these areas for additional research because results from the methodological dimensions analyses and multivariate analyses indicate that researchers have paid relatively little attention to them despite their importance. We believe that an increase in the number of studies along these lines of research would enrich and advance the community flood risk management literature. The four recommendations are: (1) more research on inland areas; (2) collect more primary and qualitative data; (3) more research on the intersection of community flood risk management and green infrastructure; and (4) more multidisciplinary approaches to flood risk management.

The results of our analysis corroborate a call for additional research on inland areas. As discussed previously, six of the reviewed empirical studies focus exclusively on inland areas compared to the 20 studies that focus exclusively on coastal areas. In addition, the 32 studies that examine both inland and coastal areas do not treat inland areas as fundamentally different from coastal areas. However, when we look at the six studies that focus exclusively on inland areas, we find that none of these studies examined two themes—planning for flood events and developing flood models and tools. Hence, there is a need for more research on inland areas of the U.S. in general, and a specific focus on planning for flood events and the development of flood models and tools. The need for additional studies is imperative due to the low flood insurance take-up rates in inland areas like the Midwest (Kousky and Kunreuther 2010), and future increases in urban development that would exacerbate inland flooding (Zahran *et al.* 2009). Moreover, previous research suggests that there are differences between inland and coastal residents concerning flood risk perception and available information on flood risk, as well as demography of vulnerable populations (Chakraborty *et al.* 2014; Kousky and Kunreuther 2010). For example, Chakraborty *et al*. 2014) note that there are more Blacks and Hispanics living in inland flood zones than in coastal flood zones. Perhaps, because of these and other differences, researchers have called for more studies in both coastal and inland communities (Brody *et al.* 2015a).

The vast majority of the studies included in this review rely on data gathered from secondary sources such as government entities (e.g., FEMA, United States Census Bureau, National Climate Data Center). We examine the relationship between author discipline and data source. The result indicates that exclusively social scientist authored-studies are far less likely to employ primary data (11% vs. 36%, t=2.31, p=0.025). This result does not hold for studies by multidisciplinary teams. Furthermore, studies in our sample that focus on perceptions and responses to flood events and policies appear to be disproportionately represented among the local studies, and lack any coverage at the national geographic scope. Hence, research involving the collection and analysis of primary data is much needed among research teams consisting of only social scientists. Similarly, the collection of primary data on perceptions and responses to flood events and policies at national level could provide important information to academics and practitioners interested in community flood risk management. Moreover, primary data collection may help address current gaps in the flood risk management literature. Such gaps include, but are not limited to, a lack of understanding of the total flood-related damage cost to uninsured property in the United States and an assessment of flood risk perceptions and flood risk characteristics outside FEMA's flood maps. In addition, researchers should collect primary data to study the impact of individual/private flood risk management on community flood risk, and the spillover effect of a community's flood risk management programs on surrounding communities' flood risks.

The result of this review also suggests the need for additional qualitative data collection. Our review indicates that studies on CRS and planning for flood event are disproportionately represented among state and national studies compared to the local level. This suggests a gap in the literature where thick description and richer, more detailed analyses of specific communities' experiences with CRS and flood event planning may be lacking. Indeed, previous research has identified FEMA's CRS program as one area that would significantly benefit from additional qualitative studies (Sadiq and Noonan 2015a). Specifically, researchers should consider conducting semi-structured interviews with CRS coordinators, floodplain managers, and emergency managers to have a better understanding of why communities choose to participate or not participate in the CRS program. Further, more data need to be collected on the costs and benefits of various flood mitigation activities within and across communities (Calil *et al.* 2015).

According to Benedict and McMahon (2012), Green infrastructure refers to the "interconnected network of green space that conserves natural ecosystems' values and functions and provides associated benefits to human populations." Examples of green infrastructure include, but are not limited to, green roofs, rain gardens, green streets, and pervious pavement (Environmental Protection Agency [EPA] 2015). There is a huge literature on green infrastructure, and some of this literature is relevant to community flood risk management. For example, researchers have examined how green infrastructure helps communities manage storm water and improve drainage systems (Benedict and McMahon 2012) and reduce the impacts of flooding (Mell 2009). However, other than the studies by Brody and his colleagues (2007a, 2007b, 2007c, 2015a), no other study included in this review examines the intersection of community flood risk management and green infrastructure despite the vast literature on the use of green infrastructure as a flood protection and flood risk management measure. The literature on community flood risk management would benefit from additional studies that explore the intersection between community flood risk management and green infrastructure. For examples, future studies might examine the tradeoffs and impacts associated with investing in green infrastructure to stem future flood losses. In addition, we urge the flood risk management community in the US to search the vast literature on green infrastructure for feasible green infrastructure strategies that could be used to manage community flood risk. In doing so, researchers studying flood risk management and those studying green infrastructure may be able to break down disciplinary silos and work together to enhance community flood risk management.

Our review indicates that the community flood risk management literature is replete with studies by social scientists. This result underscores the need for more collaborative efforts among major disciplines to study community flood risk management. Overcoming disciplinary silos and specializations maybe necessary to see more disciplines engage with notions of "community" in flood risk management studies. Fortunately, there is a track record of successful interdisciplinary work and a trend toward more multidisciplinary authorship teams. Almost half of the studies involve some multidisciplinary work that crosses the disciplinary boundaries between social science and something else (most commonly, it is natural science (Brody *et al.* 2008) or engineering (Bouwer 2011)). This multidisciplinary authorship pattern is particularly interesting considering the strong disciplinary nature of many academic journal outlets. The frequency of multidisciplinary studies, and the growing tendency for social scientists to team with non-social scientists, suggest that these disciplinary boundaries are breaking down as research grows in this area. To improve community resilience to future flood disasters, it is imperative that scholars from different major disciplines such as social science, natural science, physical science, engineering, and law work together. This is especially important due to the potential for increased flood damages due to climate change impacts such as increases in frequency, intensity, and amount of heavy precipitation (Intergovernmental Panel on Climate change 2013, Sadiq 2017).

6. CONCLUSION

Over the past five decades, scholars from a variety of disciplines have published myriad studies to better understand how communities can manage their flood risks. The present study contributes to this diverse body of literature by presenting a comprehensive and systematic review of empirical community flood risk management studies conducted in the United States. The results from this review provide scholars and policymakers valuable insights on how communities—in the United States and abroad—can better manage their flood risks. Nonetheless, the results from this review also indicate that significant opportunities exist to conduct potentially transformative multidisciplinary research that could lead to innovative policy recommendations and improve community resilience to future flood disasters. For example, more research that collects primary data and qualitative data would strengthen the community flood risk management literature and provide valuable insights regarding flood risk management decision making. Furthermore, additional research on the costs and benefits of employing green infrastructure to stem flood losses as well as the differences in flood risk management in inland versus coastal communities would likely prove beneficial. Finally, the importance of a multidisciplinary approach to understanding the multidimensional aspects of floods and its impacts on communities cannot be over emphasized. The discovery of effective flood risk management strategies is likely to be found at the intersection of multidisciplinary research. We urge scholars, especially those studying flood risk management to use this study as a platform for conducting future research that will advance the community flood risk management literature.

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Table A. Methodological Dimensions of Empirical Studies on Community Flood Risk Management

Citation	Years Studied	Coastal or Inland	Dependent Variable(s)	Independent Variable(s)	Sample Size	Analytical Approach
Albright, E. A., & Crow, D. A. (2015a)	2013	Coastal	Participatory processes Perceptions of future flood risk Problem severity Causal understanding of floods	Flood damage Resource availability Expertise (technical, environmental, social) Personal past flood experiences	58 individuals surveyed 24 interviews 773 documents	Regression
Albright, E. A., & Crow, D. A. (2015b)	2013	Inland	Participatory processes	The extent and type of damage is more severe and widespread Greater resource availability post-disaster	24 interviews 773 documents	Qualitative Approach
Asche, E. A. (2013)	1978-2010	Both	CRS participation Mitigation level Loss per claim	Risk Population Income Percent owner Repeat loss credit	615 counties 3,210 observations	Regression
Bailey, L. K. (2017)	1980-2010	Both	Reported property damage cost for all counties having a mitigation plan) Reported property damage cost for all counties without a mitigation plan Cost	Time-plan Time-after plan Timeline	108 counties 64 disaster mitigation plans	Regression
Berke, P. R., Lyles, W., & Smith, G. (2014)	Not Reported	Coastal	Not Reported	Not Reported	43 local governments with stand-alone Disaster Mitigation Act (DMA) plans (n=24 in FL, n=19 in NC) 28 local governments with DMA plans submitted under the CRS (n=17 in FL, n=11 in NC)	Regression

Blessing, R., Sebastian, A., & Brody, S. D. (2017)	1999-2009	Coastal	Flood damage	Stream distance Elevation Slope Drainage class Roughness Imperviousness Improvement value CRS Score	1,096 insurance claims	Univariate/Bivariate Analysis
Brody, S. D., Highfield, W. E., Ryu, H. C., Spanel-Weber, L. (2007c)	1991-2002	Coastal	Watershed flooding	Wetland alteration	85 watersheds	Regression
Brody, S. D., Bernhardt, S. P., Zahran, S., Kang, J, E. (2009b)	2006	Both	Flood mitigation strategies	Organizational capacity	173 jurisdictions	Univariate/Bivariate Analysis
Brody, S. D., Blessing, R., Sebastian, A., Bedient, P. (2012a)	1999-2009	Coastal	Not Reported	Not Reported	9,792 NFIP-based flood damage claims	Univariate/Bivariate Analysis and Spatial Analysis
Brody, S. D., Blessing, R., Sebastian, A., Bedient, P. (2014)	1999-2009	Coastal	Flood damage	High intensity development Medium intensity development Low intensity development Developed open space Agriculture Forest Grass Scrub Barren Palustrine wetland Estuarine wetland	1 watershed 9,792 parcels	Regression
Brody, S. D., Davis III, S. E., Highfield, W. E., Bernhardt, S. P. (2008)	1991-2003	Both	Not Reported	Not Reported	36,603 wetland alteration permits	Spatial Analysis

Brody, S. D., Gunn, J., Peacock, W., Highfield, W. E. (2011)	2001-2005	Coastal	Flood loss	High intensity development Low intensity development	144 counties	Regression
Brody, S. D., Highfield, W. E. (2013b)	1999-2009	Both	Flood damage	Open space preservation (CRS Activity 420)	450 communities	Regression
Brody, S. D., Highfield, W. E., Blessing, R. (2015b)	2001-2008	Coastal	Land use and land cover	Flood damage	2,692 watersheds 24,210 observations	Regression
Brody, S. D., Highfield, W. E., Blessing, R., Makino, T., Shepard, C. C. (2017)	2008-2014	Coastal	Flood damage	Land cover	1,782 watersheds	Regression
Brody, S. D., Kang, J. E., Bernhardt, S. (2010)	2006	Both	Structural mitigation Non-structural mitigation	Organizational capacity Percentage of floodplain Recent flood event Five-year flood loss Income Education Population change State	88 jurisdictions	Univariate/Bivariate Analysis and Regression
Brody, S. D., Kim, H., Gunn, J. (2013a)	2001-2005	Coastal	Flood losses	Development patterns	144 counties	Regression
Brody, S. D., Peacock, W. G., Gunn, J. (2012b)	2001-2005	Coastal	Flood loss	Non-floodplain area Soil permeability Wetland alteration Pervious surface	144 counties	Regression

Brody, S. D., Sebastian, A., Blessing, R., Bedient, P. B. (2015a)	2001 and 2008	Coastal	Flood damage	Distance to the 100-year floodplain Distance to the nearest stream segment Distance to the coast Imperviousness Wetland Grassland Forest Agriculture Open Space	7,183 properties	Regression
Brody, S.D., Zahran, S., Highfield, W. E., Bernhardt, S. P., Vedlitz, A. (2007b)	1997-2001	Coastal	Flood property damage	Dams Percent impervious surface Wetland alteration	423 flood events	Regression
Brody, S. D., Zahran, S., Maghelal, P., Grover, H., Highfield, W. E. (2007a)	1997-2001	Coastal	Property damage High flood-damage event	Impervious surface Dams Wetland alteration FEMA CRS (2005)	383 flood events (observations) 54 coastal counties	Regression
Brody, S. D., Zahran, S., Highfield, W. E., Bernhardt, S. P., & Vedlitz, A. (2009a)	1999-2005	Both	Class 300 (public information) Class 400 (maps and regulation) Class 500 (damage reduction) Class 600 (flood preparedness) CRS overall points	Flood frequency Flood property damage	52 counties 354 observations	Regression

Burby, R. J., & French, S. P. (1981)	1979	Both	Protection of future development from flood damage Prevention of encroachment on natural areas	Number of land use management measures used Stringency of measures used Use of subdivision or zoning regulations Use of land acquisition Level of funding Staff devoted to program Qualified personnel not available	1,203 local jurisdictions	Univariate/Bivariate Analysis
Calil, J., Beck, M. W., Gleason, M., Merrifield, M., Klausmeyer, K., & Newkirk, S. (2015)	Not Reported	Coastal	Not Reported	Not Reported	21 counties	Spatial Analysis
Chakraborty, J., Collins, T. W., Montgomery, M. C., Grineski, S. E. (2009b)	Not Reported	Coastal	Exposure to flood risk	Non-Hispanic White Non-Hispanic, Black Hispanic Median household income Below poverty Median housing value Vacant Seasonal/recreational use	1,187 Census tracts	Regression
Consoer, M., & Milman, A. (2017)	2014	Inland	Flood mitigation decisions	Physical characteristics Institutional characteristics State and federal government Third parties	27 municipalities 30 interviews	Qualitative Approach
Deegan, M. A. (2007)	1960-2010	Not Specified	Mitigation outcomes	Existing policy Policy environment Natural hazard outcomes	300 Sources	Multiple Equation Model
Esnard, A. M., Brower, D., & Bortz, B. (2001)	1997	Coastal	Past disasters, planning and hazard mitigation measures, extent of development and tax	Not Reported	4,922 parcels	Spatial Analysis

			base, status of pre-FIRM structures on developed parcels, and vacant land			
Fan, Q., & Davlasheridze, M. (35)	Not Reported	Both	ln(income) ln(housing value)	Residential location choices	281 Metropolitan Statistical Areas	Multiple Equation Model
Fan Q, Davlasheridze M. (2014)	2000	Both	Flood risk CRS creditable flood control activities	Location choice	1.8 million households located across 281 MSAs	Multiple Equation Model
Gall, M., & Boruff, B. J., & Cutter, S. L. (2007)	Not Reported	Both	Not Reported	Not Reported	3 counties in South Carolina	Spatial Analysis
Grigg, N. S., Doesken, N. J., Frick, D. M., Grimm, M., Hilmes, M., McKee, T. B., & Oltjenbruns, K. A. (1999)	1997	Inland	Not Reported	Not Reported	1 city	Univariate/Bivariate Analysis
Highfield, W. E., & Brody, S. D. (2006)	1997-2002	Both	Flood damage	Wetland alteration	67 counties	Univariate/Bivariate Analysis and Regression
Highfield, W. E., & Brody, S. D. (2017)	1999-2009	Both	NFIP-insured loss claim payments from 1999 to 2009 FEMA-provided paid NFIP loss claims	CRS participation	15,514 observations	Regression
Highfield, W. E., & Brody, S. D. (2013)	1999-2009	Both	Total damage A-V zone B-C-X	410 Additional flood data 420 Open space protection 430 Higher regulatory standard 440 Flood data maintenance 450 Storm water management 510 Floodplain management planning 520 Acquisition and relocation	450 communities 4,209 observations	Regression

				530 Flood protection 540 Damage system maintenance 610 Flood warning program 620 Levee safety 630 Dam safety		
Highfield, W. E., Brody, S. D., & Blessing, R. (2014)	1999-2009	Coastal	Property damage from flooding	CRS participation Total accumulated CRS points Point total for 14 CRS activities from series 300, 400, and 500	9,555 parcels	Spatial Analysis
Holway, J. M., & Burby, R. J. (1993).	1976-1985	Both	Land value Likelihood of development	Building elevation floodplain Building elevation floodway Zoning SUP floodplain development SUP floodway development Program organization	525 floodplain parcels 306 observations 516 observations	Regression

Kang, J. E. (2009)	2007	Both	Flood loss	Flood mitigation policies in comprehensive plan Planning capacity Budget Leadership Planner commitment Precipitation Flood duration Floodplain area Stream length Storm surge area Coastal location Impervious surface Issued permits in wetland Number of dams Population Median household income Public participation in the planning process Number of insurance policies	93 jurisdictions	Regression
Kick, E. L., Fraser, J. C., Fulkerson, G. M., McKinney, L. A., De Vries, D. H. (2011)	2004	Coastal	Ease of acceptance	Condition of property Median household income Perception of future flood risk Helpfulness of local officials 25 percent site match offered Importance of place	18 mitigation and insurance specialists at FEMA	Multiple Equation Model
Kousky, C., & Kunreuther, H. (2010)	1978-2007	Inland	Flood hazard	flood insurance policy, flood claims, and parcel location	1 county	Qualitative Approach

Kousky, C., & Walls, M. (27)	2008-2012	Inland	Price	Distance to closest park Located inside 100-year floodplain Multi-family Total plumbing fixtures Size of living area Lot size Distance to nearest major road Style code Assessor's grade code	2,170 single family homes 27,748 observations	Regression
Landry, C. E., & Li, J. (2011)	1991-2002	Both	CRS participation	Pre-CRS floods Pre-CRS damage Lag 1 floods Lag 1 damage Lag 2 floods Lag 2 damage Precipitation CAMA Water percentage Average tax Student-teacher Crime density Housing unit density Income Senior College CRS municipalities CRS Neighbor NFIP Year	100 Counties 1189 Observations	Regression
Lathrop, R., Auermuller, L., Trimble, J., & Bognar, J. (2014)	2010	Coastal	Coastal flooding vulnerability	Not Reported	61 respondents	Spatial Analysis
Li, J. (2012)	1991-2002 and 1995-2010	Both	CRS Participation	Pre-CRS Floods Pre-CRS Damage Lag 1 floods Lag 1 damage Lag 2 floods Lag damage	100 Counties 1,189 Observations	Regression

				Precipitation CAMA Water percentage Average tax Student-teacher Crime density Housing unit Income Senior College CRS municipalities CRS Neighbor NFIP Year		
Li, J., & Landry, C. E. (forthcoming)	1999-2010	Both	CRS Points	Flood Risk index Tax Staff Unemployment Student-teacher Crime Population-density Income Migration Senior	100 counties 1,200 observations	Regression
Lufoff, A. E., Wilkinson, K. P. (1979)	1975	Both	Participants and nonparticipants in the flood insurance program	Structural differentiation Structural integration (newspaper circulation and educational equality) Previous community actions Flood experience	2,463 municipalities	Regression
Mogollón, B., Frimpong, E. A., Hoegh, A. B., & Angermeier, P. L. (2016)	1991-2013	Both	Not Reported	Not Reported	31 gaged watersheds	Regression

Moore, D. E., & Cantrell, R. L. (1976)	Not Reported	Not Reported	Program status Locus of initiation Months to adoption	Flooding Planning scale Percent with all facilities Median family income Percent population increase 1960-70	93 cities and villages	Univariate/Bivariate Analysis and Regression
Noonan, D. S., & Sadiq, A. A. (2018)	1970-2010	Both	Median family income Poverty rate Top earners Gini	CRS Flood risk CRS*Risk SFHA Share CRS*SFHA Share	216,778 observations (median income) 216,884 observations (poverty rate) 216,645 observations (top earners) 216,645 observations (Gini)	Regression
Olsen, V. B. K. (2014)	Not Reported	Not Specified	Not Reported	Not Reported	10 communities 98 participants were selected to receive flood risk management meeting.	Multiple Equation Model
Paille, M., Reams, M., Argote, J., Lam, N. S. N., & Kirby, R. (2016)	2013	Both	CRS score	Median home value College-education rate 2010 government revenue Number of CRS communities Average elevation Number of total flood events	35 parishes	Univariate/Bivariate Analysis and Regression
Patterson, L. A,, & Doyle, M. W. (2009)	1990 and 2000	Both	Population and building tax value (exposure)	Not Reported	5 counties	Univariate/Bivariate Analysis
Paul, M., & Milman, A. (2017)	2013	Inland	Not Reported	Not Reported	31 town decision-makers	Qualitative Approach

Pielke Jr, R. A., & Downton, M. W. (2000)	1932-1997	Both	Flood damage	Total precipitation Number of wet days per station Number of extreme precipitation days per station Number of 2-day heavy precipitation events per station Number of 3-day heavy precipitation events per station Number of 5-day heavy precipitation events per station Number of 7-day heavy precipitation events per station Percentage of the conterminous U.S. area with much above-normal cold season (October–April) precipitation Percentage of the conterminous U.S. area with the number of wet days much above normal	1 national 9 climatic regions	Univariate/Bivariate Analysis and Regression
Posey, J. (2009)	1978-2007	Both	Participation in CRS at any level between 1 and 9 Participation in CRS at any level between 1 and 8 Participation in CRS at any level between 1 and 7 Participation in CRS at any level between 1 and 6 Discount in flood insurance rates due to participation in CRS	Loss Loss per capita Pay Pay per capita Policies Policies per capital Budget College HS dropout Median rent Median housing value City manager Net valuation Non-Hispanic whites Housing unit occupancy rate Owner occupied units Per capita income Population Individual poverty rate	10,916 observations (National Sample) 176 NJ Coastal Municipalities Selected 131 observations (New Jersey Sample)	Univariate/Bivariate Analysis, Regression, and Multiple Equation Model
Sadiq, A. A,, & Noonan, D. S. (2015b)	2012	Both	CRS participation CRS scores	ln(payroll) Property tax Flow capital Housing value	28,147 Census places	Regression and Multiple Equation Model

				Household income Year built Rent share Stay share College share No HS share White share Child share Ruralness Humidity Topography Water share Water topo Wet plains Wet topo Flood risk		
Sadiq, A. A., & Noonan, D. S. (2015a)	2013	Both	Total CRS credit points for each community	Active share Flood risk Payroll Income Housing value Population Density	28,147 Census places	Regression
Zahran, S.,, Brody, S. D., Highfield, W. E., &, Vedlitz, A. (2010)	1999-2005	Both	CRS points growth rate Stalled CRS growth CRS overall points	Threshold distance	214 local governments 1,116, 1,221, and 985 observations	Regression
Zahran, S., Brody, S. D., Peacock, W. G., Vedlitz, A., & Grover, H. (2008)	1997-2001	Both	Casualties	Precipitation (day of flood) Precipitation (day before flood) Duration Dams Percent impervious surface Property damage (log) FEMA rating Population density (log) Social vulnerability	74 counties 832 observations	Regression

Zahran, S., Weiler, S., Brody, S. D., Lindell, M. K., & Highfield, W. E. (2009)	1999-2005	Both	NFIP policies	CRS points Median home value Percent college educated Floodplain percentage Stream density Coastal county Flood frequency Flood property damage	52 counties 354 observations	Regression