



If Mitigation Saves \$6 Per Every \$1 Spent, Then Why Are We Not Investing More? A Louisiana Perspective on a National Issue

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Abstract: This paper provides an accounting of where and when mitigation and recovery investments have occurred in Louisiana, thereby generating a mitigation investment portfolio for the state. An exploratory data analysis of FEMA OpenData sets, supplemented by data on disaster damage and recovery, was conducted to develop a portfolio of mitigation actions implemented in the State of Louisiana since 1989 and to calculate damage to mitigation and recovery to mitigation expenditure ratios. Not surprisingly, Louisiana relies heavily on funding from the Hazard Mitigation Grant Program, which it largely spends on home elevations and acquisitions with limited utilization of other mitigation actions. Our analysis of Louisiana expenditures shows that, on average, residents suffer nearly \$260 in direct disaster losses for every \$1 invested in mitigation and the federal government spends \$10 on recovery for every \$1 invested in mitigation. At these levels, mitigation investments are ineffective and/or insufficient in stabilizing the state's damage trajectory. DOI: [10.1061/\(ASCE\)NH.1527-6996.0000342](https://doi.org/10.1061/(ASCE)NH.1527-6996.0000342). This work is made available under the terms of the Creative Commons Attribution 4.0 International license, <http://creativecommons.org/licenses/by/4.0/>.

Introduction

As 2017 broke new records in terms of disaster losses, recovery from billion-dollar events in 2016 (e.g., Houston flood, Louisiana floods, and Hurricane Matthew) was still ongoing. Record or near-record natural hazard events are occurring in frequent succession (CEMHS 2018), compressing and blurring phases of disaster recovery and hazard mitigation. Following disasters, residents and communities want to return to normal as quickly as possible, often rebuilding as was instead of rebuilding better (Birkmann et al. 2010; Mockrin et al. 2016). Despite tremendous advancements over the past 20 years in the knowledge base of resilient construction practices, land use planning, and risk assessments, in addition to roughly 20 years of federal hazard mitigation funding, per capita losses are increasing, rather than decreasing (Gall et al. 2011).

The value of hazard mitigation is well known: the Multihazard Mitigation Council (MMC) upped their initial estimate of \$4 (MMC 2005) saved for every \$1 spent on hazard mitigation to \$6, and \$7 with regard to flood mitigation (MMC 2017). The effectiveness of hazard mitigation, though, must go beyond quantifying the costs and benefits of individual projects alone. Managing hazard risk should involve the whole community. Aside from governmental funding, disaster risk management requires participation by non-governmental entities and a more strategic mitigation investment approach as called for in the newly released (draft) National

Mitigation Investment Strategy (NMIS) (FEMA 2018b), along with a place-based approach and utilization of the entire suite of mitigation actions such as comprehensive building codes, land use regulation, and floodplain management (Frazier et al. 2013). “Mak(ing) data- and risk-informed decisions that include lifetime costs and risks” is among the three principles of the NMIS with the “overarching goal to improve the coordination and effectiveness of ‘mitigation investments,’ defined as risk management actions taken to avoid, reduce, or transfer risks from natural hazards” (FEMA 2018b, p. 1). The National Mitigation Framework (FEMA 2016b, p. 1f) echoes the need for empirical and methodological advancements by postulating that

“(d)emonstrating clear and measurable returns on investment through mitigation is essential to build a resilient, riskconscious culture. A mature, risk-conscious culture is measured in two ways. First, it is measured by its reduction of risk to life and property. Second, it is measured by whether it has sufficient capacity to continue to promote the social, ecological, and economic vitality of the community when adapting to changing conditions or continuing essential services and recovering from an adverse incident.”

The MMC (2017) study certainly responds to the first charge and calculates the benefits of mitigation actions at the project level. However, the study does not address the effectiveness of hazard mitigation actions to stabilize rising trends in property damage, let alone reverse the trend. Furthermore, there are limited data, methods, and tools on which to base mitigation investment strategies or judge the effectiveness of strategies over space and time. Aside from a report by the Pew Charitable Trusts (2018) that investigates state-level spending on natural disasters, there is limited knowledge on what states spent mitigation funding on and if these investments truly make a difference through demonstrable reductions in risk to life and property. The research presented here aims to address this void.

This study is among the first to produce a mitigation investment portfolio and examine mitigation investment in Louisiana—the

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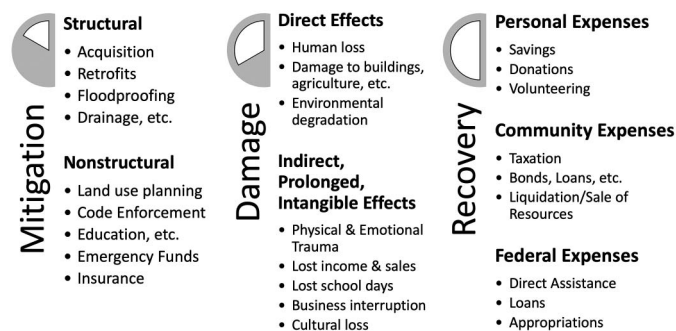


Fig. 1. Full costs of a natural hazard are not just the immediate or prolonged effects (damage). They also include the investments needed to cope with or alleviate the impacts (mitigation, preparedness) and the expenditures associated with postdisaster clean-up, building back, and more (recovery).

state that thus far, has received the most federal hazard mitigation funding according to Federal Emergency Management Agency's (FEMA) open data sets (see "Data" section). This study is situated in the research context of disaster cost accounting and seeks to fill knowledge gaps with regard to analytical processes (i.e., development of mitigation portfolios) and performance metrics (i.e., cost to investment ratios). The study summarizes locations (at the county level) where mitigation investments, recovery spending, and disaster damage have occurred and the types of projects in which funds have been invested. The paper draws on newly available data from FEMA and connect the three domains of disaster costs: damage, recovery, and mitigation (Fig. 1) through the analysis to investigate: (1) what mitigation actions have been implemented; and (2) if these actions have a measurable damage-reducing effect. This review of Louisiana's mitigation profile allows the identification of underutilized and/or overutilized project types, effectiveness in reducing disaster losses, locations in need of more mitigation investments, and identifies possible points of entry for hazard mitigation programs or incentives for the state and local jurisdictions. This is particularly important because under the current federal-state-local funding context, mitigation and recovery projects are proposed by local jurisdictions—which may or may not be part of local long-term strategies—and project value is considered at the state and federal levels on a case-by-case basis using project costs and benefits. This context does not guarantee nor necessarily encourage projects that fit into a broader, long-term strategy at the regional or state levels.

The information and approach developed by this study are critical information—both empirically and methodologically—given that FEMA's new strategic plan (FEMA 2018a) calls for quadrupling mitigation spending in the nearby future but fails to identify performance measures—measures that are invaluable to make risk-informed decisions and assess the effectiveness of mitigation investments, but also suitable to for local jurisdictions to "share responsibility and accountability with the federal government" (FEMA 2018b, p. 1). The lack of an investment "baseline" and the paucity of decision tools for identifying best (or better) mitigation practices makes it difficult for planners and stakeholders to diverge from business-as-usual decisions. Hazard mitigation planners have only limited metrics to track or monitor their state's portfolio of mitigation and recovery—mostly relying on their day-to-day experience and institutional knowledge. This study gives planners and others in the State of Louisiana and beyond an empirical basis for identifying new mitigation priorities, re-examine their mitigation portfolios, and judge the value of mitigation projects beyond benefit-cost analysis.

Background

Existing research on hazard mitigation focuses on:

1. the value of individual mitigation or preparedness options such as insurance (e.g., Kunreuther 2017), structural (e.g., Li 2012) or nonstructural (e.g., Meyer et al. 2012) activities using either actual case studies (e.g., Meo et al. 2004; Orooji and Friedland 2017) or what-if (e.g., Remo and Pinter 2012) scenarios;
2. cost efficiency assessments including cost-benefit-analysis (e.g., Špačková and Straub 2015) and other project-level methodologies (e.g., Noori et al. 2018);
3. incentives and challenges to implementing mitigation actions, such as organizational capacity (e.g., Brody et al. 2010) or household behavior (e.g., Ge et al. 2011);
4. risk assessment techniques (e.g., Gallina et al. 2016), hazard mitigation planning (e.g., Lyles et al. 2014), and policies (Berke et al. 2014); and
5. economic cost accounting of natural hazards including loss estimation (e.g., Rose 2009), and quantification of avoided losses (e.g., MMC 2017).

In the past, emergency management has largely focused on the preparedness and response phase of the emergency management cycle with marginal improvements in the practice of hazard mitigation (Rubin 2012). At present, transfer of mitigation knowledge is largely limited to modifications to the National Flood Insurance Program (e.g., Kousky and Shabman 2017), updates model building code recommendations (Ramseyer et al. 2017), advancements in material science (Middleton 2018), and improvements in construction practice (English et al. 2017), while hazard mitigation planning remains insulated from community and comprehensive planning (Schwab 2010).

The only planning activities that are mandated are state and local hazard mitigation plans as required by the Disaster Mitigation Act of 2000 (Public Law 106-390) to maintain eligibility for post-disaster funds. These mitigation plans are not strategic planning documents in the sense of comprehensive or community plans, let alone comprehensive roadmaps for implementing or investing in risk reduction actions. They are generally more a list of generic actions to remain compliant with federal funding requirements (Horney et al. 2017; Lyles et al. 2014; Smith et al. 2013).

This requirement for funding compliance has undermined the initial intent, i.e., designing mitigation strategies tailored to local communities for the purpose of long-term risk reduction, of the Disaster Mitigation Act (DMA) of 2000. Berke et al. (2014) found in their review of hazard mitigation plans that there is "emphasis placed on the identification of discrete hazard mitigation projects (is) indicative of a planning process driven by federal grant programs that disproportionately fund single mitigation projects, perhaps resulting in strong emphasis on plans that identify these projects rather than simultaneously adopting a more future-oriented, land use-focused plan" (2014, p. 70). Thus, funding considerations tend to guide the development of a mitigation plan rather than the design of a long-term mitigation strategy coordinated with economic development, capital development plans, and comprehensive community development.

Communities are free to pursue and implement hazard mitigation projects, structural and nonstructural, independent of a hazard mitigation plan or without federal financial support. According to a recent study that examined state expenditures between 2012 and 2016, investments are highly variable among states, ranging from no state-funded efforts to some pursuing their own mitigation programs such as reimbursements for tornado safe rooms in Arkansas, flood mitigation funds in Iowa, or flood control and property acquisition in North Dakota (Pew Charitable Trusts 2018). Not surprisingly, Pew's

review concluded that the vast majority of mitigation dollars come from federal sources, while local initiatives, programs, and/or funding are the exception. However, these local initiatives exemplify the whole community approach and are a manifestation of shared responsibilities.

Recovery and mitigation dollars are limited. The federal government is exploring ways to limit its financial exposure, as the disaster deductible proposal (Federal Register 2017) and offloading of flood insurance liabilities to the financial markets (reinsurance) (FEMA 2017) or private insurers (Kousky 2017) show. The adoption of the whole community approach by FEMA during the Obama Administration and continued by a culture of preparedness under the Trump Administration calls on everyone (i.e., citizens, private and nonprofit sector) to do their share in reducing risks and impacts.

But what would be the empirical basis for a municipality, county, or state to implement local mitigation programs? Based on what information would decision-makers argue for or against such programs and how could such programs be justified over time? FEMA's latest strategic plan indicates a move toward measures of accountability and performance metrics but as mentioned previously, methods beyond project-level benefit-cost analysis are lacking. Given the economic scale of disaster losses and in light of increasing trends and projections of hazard frequency and intensity (Emanuel 2005; Webster et al. 2006), more work is needed to quantify and assess the benefits of hazard mitigation, consider location and hazard governance, identify the most effective suite of mitigation actions and

their cumulative effects, the best timing for their implementation, postmitigated levels of risk, and more to devise truly effective hazard mitigation strategies and maximize mitigation investments (Fung and Helgeson 2017).

Hazard Mitigation in Louisiana

As a coastal state situated along the Gulf of Mexico, Louisiana frequently experiences hurricanes and tropical storms; riverine, coastal, flash, and storm surge flooding; coastal erosion; nuisance flooding from high tides; subsidence and sea-level rise; tornadoes; severe thunderstorms; winter weather; wildfires; drought; and more (GOHSEP 2014) (Fig. 2). Since 1960, Louisiana has suffered more than \$100 billion (in \$2016) in direct damage (CEMHS 2018). The costliest disasters in the state's history were 2005 Hurricane Katrina and the 2016 floods that hit Louisiana's capital city (Baton Rouge) region especially hard (NCEI 2018). Hurricane Katrina still serves as a defining event in Louisiana's recent history, and subsequent disasters continue to expose the state's vulnerabilities: high rates of poverty, low rates of flood insurance, reliance on flood control infrastructure, and a substantial share of buildings in the Special Flood Hazard Area built with floor elevations below the base flood elevation (BFE), among others.

Louisianans have long considered flooding a coastal problem associated with hurricanes and tropical storms, as proven by the low number of flood insurance policies and timid participation of communities in the Community Rating System (CRS). The National



Fig. 2. Parish (county) map of Louisiana.

Flood Insurance Program (NFIP) insures about one-half million policyholders in the state, covering approximately \$130 billion of assets (roughly 10% of the entire NFIP portfolio), trailing Florida with 1.8 million policies and Texas with 630,000 policies. Louisiana ranks first in NFIP pay-outs, however, with nearly \$20 billion, followed by Texas with \$16 billion and Florida with \$5 billion (FEMA 2018d). Only 17 out of 64 parishes and only 30 out of 308 municipalities participate in the CRS, an incentive program for good flood risk management practices that provides residents with discounts on flood insurance premiums for participating communities (FEMA 2016a). Nearly one-third of the state's parishes (20 out of 64 parishes) are considered coastal (DNR 2012) and these parishes are home to almost half of the state's total population of 4.7 million residents.

Unlike most other Gulf Coast states, Louisiana's coastline is not defined by sandy beaches and tourism. It is a working coast, where oyster and shrimp fisheries coexist and share (or compete for) resources with oil, gas, and chemical industries (CPRA 2017). The Mississippi River is a highway for the shipment of goods, petrochemical products, and grains, most of which are processed through the Port of New Orleans. The economic importance of Louisiana's coast to the nation has justified decades of flood control investments through the US Army Corps of Engineers and development in high-risk areas to provide housing for the local workforce. Flood protection and a heavily engineered flow of water, though, along with miles of pipelines transecting the coast, have led to a decline of coastal wetlands, land loss, and an increased susceptibility to sea-level rise, storm surge, hurricane, coastal flooding, and more (CPRA 2017).

The State of Louisiana, cognizant of the conflicts between economic demands, flood risk management, and environmental protection, estimates that a \$50 billion investment is necessary to protect coastal assets and residents. Proposed investments would be split between structural mitigation projects (\$19 billion), marsh creation (\$18 billion), nonstructural mitigation projects (\$6 billion), sediment diversion (\$5 billion), and more (CPRA 2017). This would be on top of any future disasters or related recovery and mitigation costs that may arise. With decades of funding received through various federal mitigation programs, billions of recovery dollars spent especially since 2005 (Hurricane Katrina), and continued investments in hazard mitigation in accordance with Louisiana's hazard mitigation plan (GOHSEP 2014) being inevitable, it is time to assess the state's portfolio of hazard mitigation investments and the loss-reducing effect of these investments at the parish and state level.

Data

Federal data sets on mitigation and recovery spending only recently became available through FEMA's OpenData initiative in 2015 and 2016 (Table 1). These data sets, most of which are updated quarterly, have evolved substantially over the past few months with frequent alterations/modifications to content, attributes, and more. The downloadable FEMA data are raw, unedited data from FEMA's Mitigation eGrants system and the National Emergency Management Information System (NEMIS). These data sets are accessible individually either through APIs or simple Excel spreadsheets without any analytical capabilities or data linkages. Some spreadsheets must be merged (e.g., individual assistance and public assistance) to arrive at a complete thematic data set. The data sets obtained for this study relating to disaster history, direct damage, mitigation investments, and recovery expenditures are described in Table 1.

Mitigation investment data utilized in this study are based on the three federal mitigation funding sources available to a community

to recoup or offset projects costs: the Hazard Mitigation Grant Program (HMGP, Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act as amended through the DMA 2000), the Pre-Disaster Mitigation program (PDM, Section 203), and the Flood Mitigation Assistance program (FMA, Section 1366 of the National Flood Insurance Act of 1968). HMGP funds are limited to states that have received Presidential Disaster Declarations (PDDs), meaning a disaster large enough to overwhelm local and state capacities. HMGP-funded mitigation projects require usually a 25% cost share (also called cost match) by local jurisdictions, which can be reduced to 20% if states have an Enhanced Hazard Mitigation Plan (McCarthy 2014). FEMA pays the remaining 75% (or 80%) of project costs. A state's emergency management agency administers these federal dollars.

Per DMA 2000, HMGP funds are calculated as a share of the total sum of individual assistance (IA, officially called the Individuals and Households Program, IHP) and public assistance (PA), and dispersed 1 year after the disaster declaration: 15% when IA/PA is less than \$2 billion, 10% for IA/PA more than \$2 billion but less than \$10 billion, and 7.5% for a disaster of more than \$10 billion in federal assistance (Kreiser et al. 2018). IA and PA monies are to be used exclusively for immediate disaster recovery purposes. IA provides financial and direct services to eligible individuals and households affected by a disaster who have uninsured or underinsured necessary expenses and serious needs and may include rental assistance, lodging expense reimbursement, home repair assistance, and home replacement assistance, temporary housing assistance. IA also includes so-called other needs assistance (ONA), which provides some personal property assistance, transportation assistance, moving and storage assistance, funeral assistance, medical and dental assistance, child care assistance, and other items assistance. PA provides supplemental funds for debris removal, emergency protective measures, and the repair, replacement, or restoration of disaster-damaged, publicly owned facilities, and the facilities of certain private nonprofit (PNP) organizations.

PDM and FMA programs receive annual allocations by Congress, but their funding levels are much lower than HMGP. In fiscal year (FY) 2018, the PDM program saw appropriations of \$235.2 million, a substantial increase over previous years, which on average had been \$80 million (FEMA 2018c), and the FMA program received \$160 million (FEMA 2018c). Funds for both programs are shared among all US states, local, territorial, and tribal governments (SLTTs). PDM and FMA project proposals are submitted by local jurisdictions (as subapplicants) through the state's emergency management agency and compete nationwide. For approved mitigation projects under the PDM and FMA programs, FEMA provides funding for 75% of project costs, even up to 90% for impoverished communities (FEMA 2015).

In addition to FEMA, there are other sources of disaster recovery funding such as at Department of Housing and Urban Development's Community Development Block Grant Disaster Recovery program (CDBG-DR), the USACE Flood and Storm Damage Reduction Projects, the USDA, and others. Of these other funding sources, this study only includes CDBG-DR funding data since these funds are managed at the state level with the potential for strategic mitigation investments. CDBG-DR funds become available through congressional supplemental appropriations after catastrophic events only. Since FY 1999, Congress appropriated about \$45 billion for CDBG-DR (Carter et al. 2017). CDBG-DR funds do not require a project cost share by local jurisdictions—in fact, jurisdictions may use CDBG-DR funds as the local cost share for HMGP, PDM, or FMA projects. At the discretion of the grantee, CDBG-DR funds can be used for hazard mitigation activities (e.g., acquisition, retrofit and improvement projects, and land use planning), which de

facto should be a major incentive since it allows for the implementation of mitigation projects without any local funding. However, CDBG-DR and USACE funds are largely used for recovery rather than mitigation (Kousky and Shabman 2017).

It is important to point out differences in data availability due to variability in program start dates and data reporting. Funds became available starting in 1989 for HMGP, 2004 for PDM, and 1997 for

FMA. Public and individual assistance have been provided by the federal government for decades under the 1950 Disaster Relief Act as well as through disaster-specific appropriations but data availability through FEMA OpenData dates only back to 1999 (PA) and 2004 (IA) for Louisiana. CDBG-DR funds became only available in 2006, 2008, 2013, and 2016. CDBG-DR data are only available as a running total at the state level, so there are no annual figures

Table 1. Data sources utilized to quantify hazard mitigation expenditures and analyze portfolio of projects

Data type	Source	Time period covered	Value extracted	Utilized to quantify
PDD	FEMA OpenData (first released 5/04/2015); raw, unedited data from FEMA's National Emergency Management Information System (NEMIS)	1953–2016	- Declared parish - IHP program declared - IA program declared - PA program declared - HM program declared - Disaster type - Incident type - Incident title - Incident begin and end date	Disaster history; recovery
FEMA HMGP	FEMA OpenData (first released 2/1/2016); amount of HMGP funding available to Applicant is based upon the total Federal assistance for disaster recovery under the PDD. This dataset lists all HMGP Projects stored in the National Emergency Management Information System (NEMIS; raw, unedited data), some of which are historical entries; contains funded (financial obligation to grantee); open projects still under pre-obligation processing are not represented.	1989–2017	- PDD number - Declaration date - Incident type - Disaster title - Project/activity type - Project title - Project status - Subgrantee - Federal share obligated - Cost share percentage	Mitigation
FEMA PDM	FEMA OpenData (first released 2/29/2015); raw, unedited data from FEMA's Mitigation eGrants system	2000–2016	- Program fiscal year - Project approval data - Project parishes - Type (of project) - Project type (title) - Federal share obligated - Cost share percentage	Mitigation
FEMA FMA	FEMA OpenData (first released 2/27/2015); raw, unedited data from FEMA's Mitigation eGrants system	1997–2016	- Program fiscal year - Project approval data - Project parishes - Project title - Type (of project; incomplete) - Project type (title; incomplete) - Federal share obligated - Cost share percentage	Mitigation
Population data	US Census Bureau	1960–2016	Decadal parish population for 1960s and 1970s distributed incrementally	Per parish capita
Inflation values	Bureau of Labor Statistics	1960–2016	Consumer price index (CPI) inflation factor	Direct damage
Direct damage	SHELDUS version 16	1960–2016	- Property damage - Crop damage - Injuries - Fatalities	Direct damage
FEMA PA	FEMA OpenData (first released: 1/21/2010); raw, unedited data from NEMIS; lists all public assistance recipients (subgrantees) and a summary of the funded program support	1999–2017	- PDD number - Declaration date - Incident type - Parish - Applicant name - Number of projects - Federal share obligated	Recovery

Table 1. (Continued.)

Data type	Source	Time period covered	Value extracted	Utilized to quantify
FEMA IA/IHP	FEMA OpenData (first release on 7/13/2014); raw, unedited data from FEMA's National Emergency Management Information System (NEMIS), excludes personally identifiable information	August 2004 (DR-1539) to February 2013 (DR-4101); 2013–2015; 2016 (DR-4263, 4277, 4300)	• PDD number • Number of FEMA applicants who were approved for FEMA's IHP assistance (renter) • Number of FEMA applicants who were approved for FEMA's IHP assistance (owner) • Total amount approved under FEMA's IHP program (renter) • Total amount approved under FEMA's IHP program (owner)	Recovery
HUD CDBG-DR	Monthly CDBG-Dr grant financial report (HUD 2018)	2006–2016	• Grantee (state) • Grant number • Grant award	Recovery

Table 2. Summary of presidential disaster declarations and funded mitigation projects by funding source (1989–2016)

Year	PDD	HMGP	PDM	FMA
1989	DR-829 (flood)	1	—	—
	DR-833 (storms) ^a	—	—	—
	DR-835 (TS Allison)	1	—	—
	DR-849 (flood) ^a	—	—	—
1991	DR-902 (flood)	3	—	—
	DR-904 (severe storms)	1	—	—
1992	DR-956 (Andrew)	6	—	—
1993	DR-978 (floods) ^a	—	—	—
1994	DR-1012 (ice storm)	5	—	—
1995	DR-1049 (flood)	33	—	—
1997	DR-1169 (winter storm)	1	—	8
1998	DR-1246 (George, TS Frances)	10	—	10
1999	DR-1264 (ice storm)	4	—	8
	DR-1269 (severe storm)	8	—	—
2000	DR-1314 (snow)	1	5	11
2001	DR-1357 (ice storm)	5	—	11
	DR-1380 (TS Allison)	21	—	—
2002	DR-1435 (TS Isidore)	23	—	11
	DR-1437 (Lili)	30	—	—
2003	—	—	4	9
2004	DR-1521 (severe storms)	4	3	3
	DR-1548 (Ivan)	5	—	—
2005	DR-1601 (TS Cindy)	1	2	—
	DR-1603 (Katrina)	424	—	—
	DR-1607 (Rita)	125	—	—
2006	DR-1668 (severe storms)	2	—	1
2007	DR-1685 ^a	—	3	—
2008	DR-1786 (Gustav)	170	—	2
	DR-1792 (Ike)	28	—	—
2009	DR-1863 (severe storms)	2	1	—
2011	DR-4015 (flood)	3	—	4
	DR-4041 (TS Lee)	2	—	—
2012	DR-4080 (Isaac)	30	7	3
2013	DR-4102 (severe storms)	1	2	7
2014	—	—	6	12
2015	DR-4228 (flood)	2	4	12
2016	DR-4263 (flood)	6	1	6
	DR-4277 (flood) ^b	1	—	—
Total	36	959	38	118

Note: HMGP-projects are tied to the declaration year whereas PDM and FMA projects use the fiscal year in which projects were funded.

^aPDD did not trigger HMGP funding.

^bAt the time of analysis, no HMGP funds had been allocated for the 2016 flood although about \$1.3 billion in IA and PA were allocated.

provided on parish allocations. Further, it is also important to note that this study does not provide a full accounting, as it excludes federal insurance payouts (e.g., NFIP and USDA crop insurance), private insurance payouts (e.g., wind insurance and homeowners insurance), indirect damage (e.g., business interruptions and lost wages), costs of injury and trauma, household expenditures (evacuation, relocation, etc.), business stimulus (e.g., construction sector), and more (Rose 2009).

Methodology

This study is unique in its combination of disparate data sources, which have not been previously linked or analyzed in conjunction with each other. This is largely due to the fact that the FEMA data have only been accessible since 2015/2016 as raw data, requiring extensive data clean-up to remove unfunded projects, projects without allocated funds, partially spent funds, etc. Furthermore, FEMA data sets lack a common identifier aside from PDD. For data sets that only reference a PDD number, the year of the event was utilized as the reference year.

Given the aim of this study, all data sets were georeferenced at the parish level, adjusted for inflation (base year: 2016), and population. Population adjustments at the parish level are a valuable tool to account for the relative impacts of direct damage and mitigation and recovery investments locally. These per parish capita figures were calculated as the inflation-adjusted value (of a recovery expenditure, mitigation project, or direct damage) divided by the current parish population at the time of the event or declaration. For example, a 2008 mitigation project in Calcasieu Parish had a reported federal obligation amount of \$364,871, equivalent to \$407,055 in 2016 dollars. In 2008, the population in Calcasieu Parish was 185,872. Dividing the inflation-adjusted federal obligation amount by the 2008 population produces a per parish capita value of \$2.19 (in 2016 dollars).

All mitigation projects were evaluated with respect to funding source, project type, investment level, and project location. For state-wide projects, primarily related to project management and planning, the project costs were first inflation-adjusted and then a per capita value (based on Louisiana population) was calculated. For projects involving multiple parishes, projects costs were equally split among the parishes regardless of population size.

Hazard mitigation investments were calculated as the sum of project expenditures implemented under the HMGP, PDM, and

FMA programs. The calculated total project cost consisting of the sum of federal and local cost shares was utilized throughout this study, rather than project amounts reported in the application or in the original data sources. For mitigation projects reporting only a federal obligation value (and federal share percentage), the project costs carried by the local community were calculated as well. Mitigation projects that had a project amount but no federally obligated amount were eliminated.

Recovery costs were calculated as the sum of expenditures related to PA, IA (IHP and ONA), and HUD CDBG-DR. Recovery costs only capture federal expenditures and are not reflective of additional state or local expenditures.

Direct damage, mitigation investments, and recovery expenditures are reported subsequently by parish as both total and per parish capita values. Using the per parish capita values, ratios of direct damage to recovery expenditures, direct damage to mitigation expenditures, and mitigation to recovery expenditures were calculated to elicit the relationships between disaster damage and recovery and mitigation investments, and to examine if mitigation (and/or recovery expenditures) has made a lasting impact in reducing disaster damage in Louisiana.

Results

Mitigation Portfolio: Most Mitigation Funds Invested in Property Elevation

Since 1989, Louisiana has received 36 PDD, an average rate of 1.3 PDDs per year. Between 1956 and 2016, the state experienced 75 disasters that were large enough to trigger declarations, 84% of which were PDDs. Most declarations were caused by floods (26),

hurricanes (23), or severe storms (14). From 1989 to 2016, only 4 years were declaration-free.

A total of 959 HMGP-funded projects have been implemented since 1989—compared with 38 PDM-funded projects since 2000 and 118 FMA-funded projects since 1997 (Table 2). With HMGP-funding being tied to disaster occurrence, the availability of HMGP-funds fluctuates considerably in Louisiana. More than half of the state's projects (550) were the product of hazard mitigation funding related to the 2005 hurricane season. The 2008 hurricane season triggered 198 mitigation projects. Excluding the mitigation projects from 2005 and 2008, the average annual number of mitigation projects is 11 projects. The parishes with the most projects are St. Tammany (93), Lafourche (65), Calcasieu (50), Orleans (45), Jefferson (44), and Terrebonne (40). There were 44 projects of mostly planning or administrative nature that had statewide impacts.

PDM funds are largely spent on planning activities and management costs rather than structural projects. Under PDM, only one acquisition project was funded in St. Tammany Parish, one elevation project of a repetitive loss property in Terrebonne Parish, one safe room project in Jefferson Parish, and five wind retrofitting projects for public buildings in Jefferson (4) and St. Charles Parishes. Acquisition and elevation of private property are the most commonly funded FMA projects, followed by planning activities. Other flood-mitigation activities such as stormwater management, green infrastructure, or wet flood proofing are nearly absent in the portfolio of FMA projects.

Out of the 959 HMGP-funded mitigation projects (Table 3), 257 projects consisted of local flood risk and stormwater management (code 403.x, 404.1, and 405.1) followed by 185 wind retrofitting projects of mostly public structures (code 205.7, 205.8), and

Table 3. Louisiana's mitigation portfolio showing count of projects by mitigation category and grant program along with total project amounts in million

Mitigation category	HMGP	PDM	FMA	Amount	Mitigation category	HMGP	PDM	FMA	Amount
Property acquisition and structure demolition (200.x)	110	1	22	\$174.9	Soil stabilization (300.x, 301.x)	2	—	—	\$0.8
Property acquisition and structure relocation (201.x)	2	—	—	\$1.0	Wildfire mitigation (205.1/2, 300.2, 300.8, 304.1)	—	—	N/A	—
Structure elevation (202.x)	163	1	47	\$1,065.4	Postdisaster code enforcement (104.1), professional education (101.1)	24	N/A	N/A	\$14.9
Wet floodproofing (203.x)	6	—	1	\$2.7	Advance assistance (904.1)	—	N/A	N/A	—
Mitigation reconstruction (207.x)	40	—	3	\$407.7	5% initiative projects	—	N/A	N/A	—
Dry floodproofing (204.x)	6	—	1	\$3.3	Aquifer and storage recovery (403.6)	—	—	—	—
Generators (601.x, 602.x)	22	—	N/A	\$164.1	Flood diversion and storage (403.5, 403.8)	—	—	—	—
Localized flood risk reduction projects (403.1–403.4, 404.1, 405.1)	257	—	2	\$367.5	Floodplain and stream restoration (303.1–303.3)	—	—	—	—
Nonlocalized flood risk reduction projects (500.x, 501.1)	23	—	N/A	\$45.3	Green infrastructure (403.7)	—	—	2	\$11.3
Wind retrofitting of existing buildings (205.7, 205.8)	185	5	N/A	\$138.4	Miscellaneous/other (100.1, 106.1, 800.1)	12	—	3	\$40.1
Nonstructural retrofitting of existing buildings and facilities (205.3, 205.4)	—	—	—	—	Hazard mitigation planning	148	24	23	\$42.7
Safe room construction (206.x)	44	1	N/A	\$51.4	Technical assistance (701.x)	N/A	N/A	2	\$0.5
Infrastructure retrofit (400.x–402.x)	65	—	—	\$220.0	Management costs (700.x)	13	6	5	\$139.1
Feasibility and design studies (103.x) applied R&D (105.1)	44	—	—	\$9.0	Warning systems (600.1)	2	—	—	\$4.2

Note: The count of mitigation projects exceeds project totals since each activity of multitype projects was counted. The project amount of multitype projects was equally split across the project types with the exception of feasibility studies for which a default share of 10% was assumed.

163 projects related to property elevations, mostly private properties related to riverine flooding (code 202.x). The price tag associated with elevating structures exceeded \$1 billion (out of the \$2.7 billion in HMGP funds). The 43 projects related to mitigation reconstruction (code 207.x), i.e., the construction of a new and mitigated building on the same site where the prior building was partially or completely demolished or destroyed, cost more than \$407 million. Louisiana spent more than \$367 million on local flood risk and stormwater management and 259 local flood risk reduction projects.

Overall, there is a reliance on structure elevation, acquisition, and reconstruction. While effective in terms of disaster risk reduction, these projects tend to offer very localized benefits compared to other types of mitigation projects that may reduce risks for entire neighborhoods or the community at large. Stormwater management projects, for example, tend to reduce risk beyond a very small locale but can also be quite costly. In Louisiana, the implementation of local flood risk projects had a per parish capita cost of \$6,149, which was significantly higher than the per parish capita costs for structure elevation (\$4,318) or wind retrofitting (\$2,943). The most cost-efficient project types with the lowest absolute project costs (total of \$14.9 million) and per capita cost (\$7) were code enforcement, standard, ordinances, and professional education (code 104.1 and 101.1).

Mitigation Investments are Low, Unable to Stabilize Louisiana's Damage Trajectory

In total, disasters have cost the state \$98.5 billion since 1960 (Figs. 3 and 4). To recover from disasters, Louisiana has received more than \$46 billion in IA, PA, and CDBG-DR funds with subsequent mitigation expenditures of \$2.9 billion (Fig. 3 and Table 4).

Table 4 provides parish-level total and per parish capita values for direct damage, mitigation, and recovery expenditures. Ratios of damage to recovery expenditures, damage to mitigation expenditures, and recovery to mitigation expenditures are

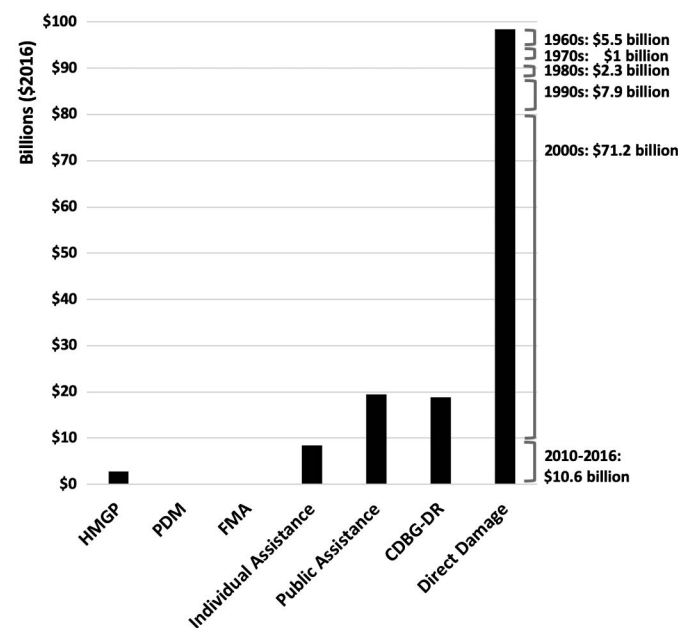


Fig. 3. Recovery and mitigation expenditures by program along with direct damage by decade.

discussed in the next section. Fig. 4 provides geographical context to the results.

Damage

Not surprisingly, there is a south/southeast to north gradient with regard to direct damage: most direct damage has occurred in southeastern Louisiana with parishes having experienced more than \$2 billion in direct damage between 1960 and 2016 [Fig. 4(a)]. Jefferson, Orleans, St. Bernard, St. Tammany, Lafourche, and Plaquemines Parishes have each experienced more than \$8 billion in direct damage. All parishes in the southern half of Louisiana have seen at least more than half a million in direct damage, while most parishes in the northern half have experienced less than \$150 million in direct damage with the exception of urban areas such as Shreveport (Caddo Parish). Among the northern parishes, East Carroll Parish stands out with nearly \$1 billion in direct damage and nearly \$110,000 in damage per parish resident.

Average per parish capita direct losses amount to \$32,463 across Louisiana. The parishes with the highest per parish capita direct damage are Plaquemines (\$285,639), St. Helena (\$155,676), St. Bernard (\$127,227), East Carroll (\$109,467), and West Feliciana (\$101,705)—parishes affected by Hurricane Katrina and recent flood disasters. The parishes with the lowest per parish capita direct damage are Caddo (\$1,642), Ouachita (\$1,893), Webster (\$2,901), Natchitoches (\$3,428), and Lincoln (\$3,476)—northern parishes that generally do not experience large regionally, devastating disasters.

Recovery

Average per parish capita recovery expenditures amount to \$3,278 across Louisiana. Parishes with the highest per parish capita recovery expenditures are Plaquemines (\$46,170), St. Bernard (\$41,498), and Cameron (\$37,773)—all lower density, rural parishes—along with Orleans (\$21,215) and East Baton Rouge (\$6,446), two of the most populous parishes in Louisiana. Parishes with the lowest per parish capita recovery expenditures are Caddo (\$46), Lincoln (\$69), Bienville (\$97), and Jackson and Red River (\$99). Keeping in mind the mismatch in time periods covered by the data sets and the glaring underestimation of recovery costs (GAO 2016), this study estimates that the federal government has likely spent more than \$100 billion on rebuilding public infrastructure and disaster recovery in Louisiana.

Mitigation

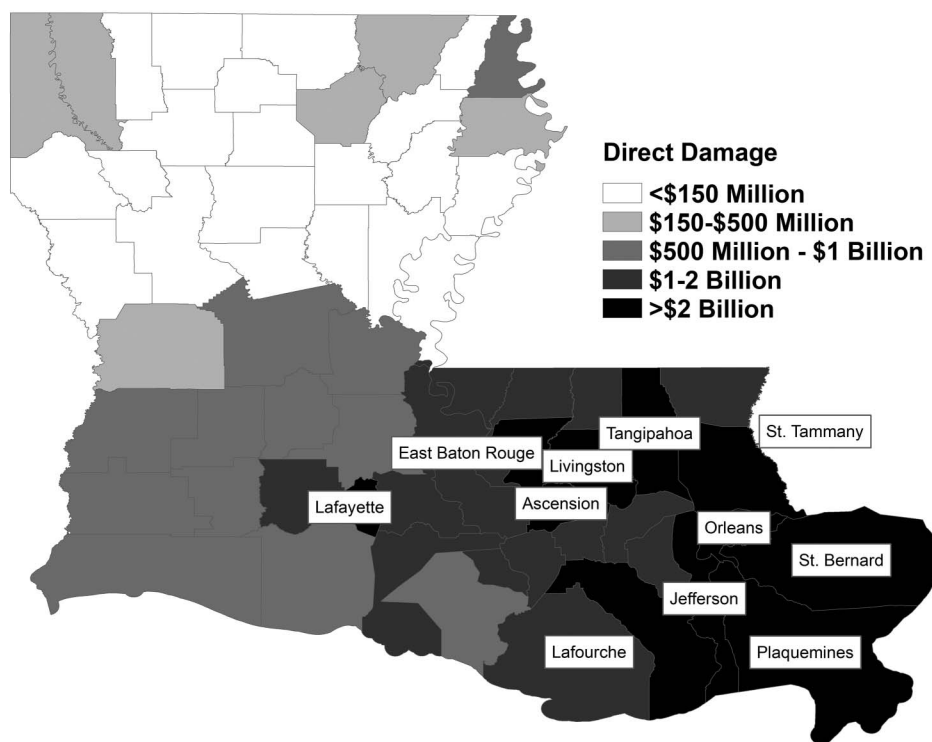
In stark contrast to these catastrophic damage figures, hazard mitigation investments in Louisiana are meager, even when including local cost shares as done in this study: close to \$3 billion in mitigation projects have been implemented since 1989, out of which only \$167 million came from FMA and \$15 million from PDM. Louisiana's most significant source of mitigation funds is the HMGP (\$2.7 billion), received postdisaster.

The parishes that received the most mitigation funds were Jefferson (\$330 million), Orleans (\$275 million), St. Tammany (\$167 million), Terrebonne (\$122 million), and Plaquemines (\$105 million)—parishes devastated by Hurricane Katrina. Note that these figures exclude funds from statewide projects (\$1.3 billion). Taking population into account, average per parish capita mitigation expenditures amount to \$334 across Louisiana. The highest per parish capita mitigation investments occurred in Plaquemines (\$3,851), Cameron (\$1,810), St. Charles (\$1,239), St. Bernard (\$1,160), and Terrebonne (\$1,135), i.e., parishes of more rural character and less population than parishes like Orleans or East Baton Rouge Parish. Given that these figures do not yet consider mitigation projects funded as a result of the 2016 August flood disaster, the per parish capita figures, especially for

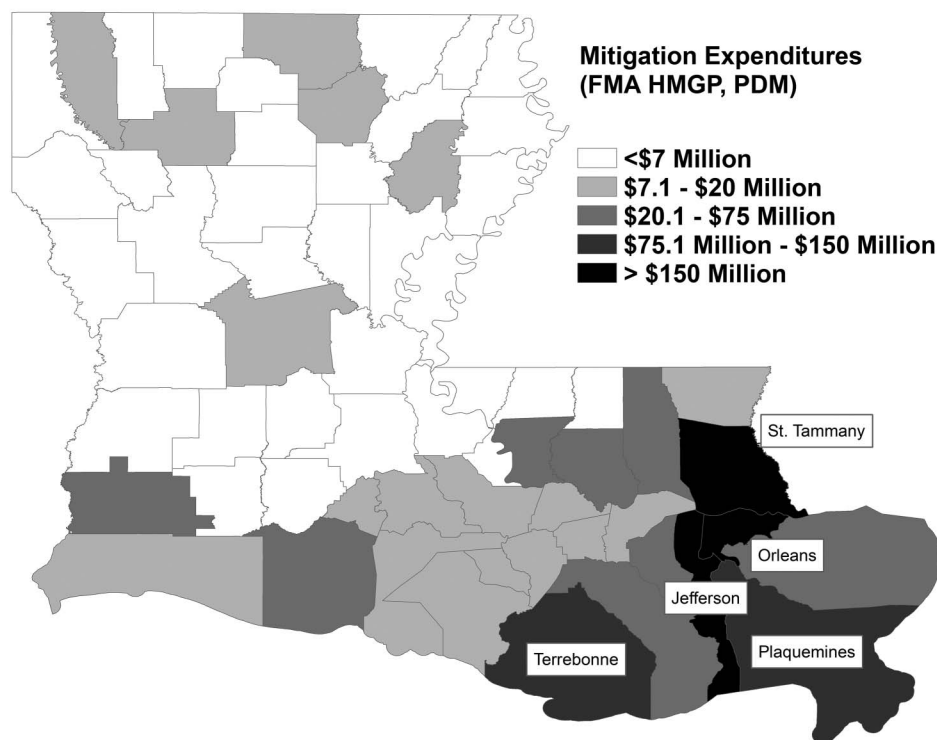
East Baton Rouge parish, are likely to change. The lowest per parish capita mitigation expenditures occurred in LaSalle (\$4), Webster (\$5), Natchitoches and DeSoto (\$7), and Morehouse (\$9)—more rural, central, and northern parishes.

Damage Trajectory

Excluding pre-1989 events (more than half of the state's PDDs), the direct damage since 1989, both in absolute values and calculated as per parish capita, continue to rise (Fig. 5). Even when excluding the

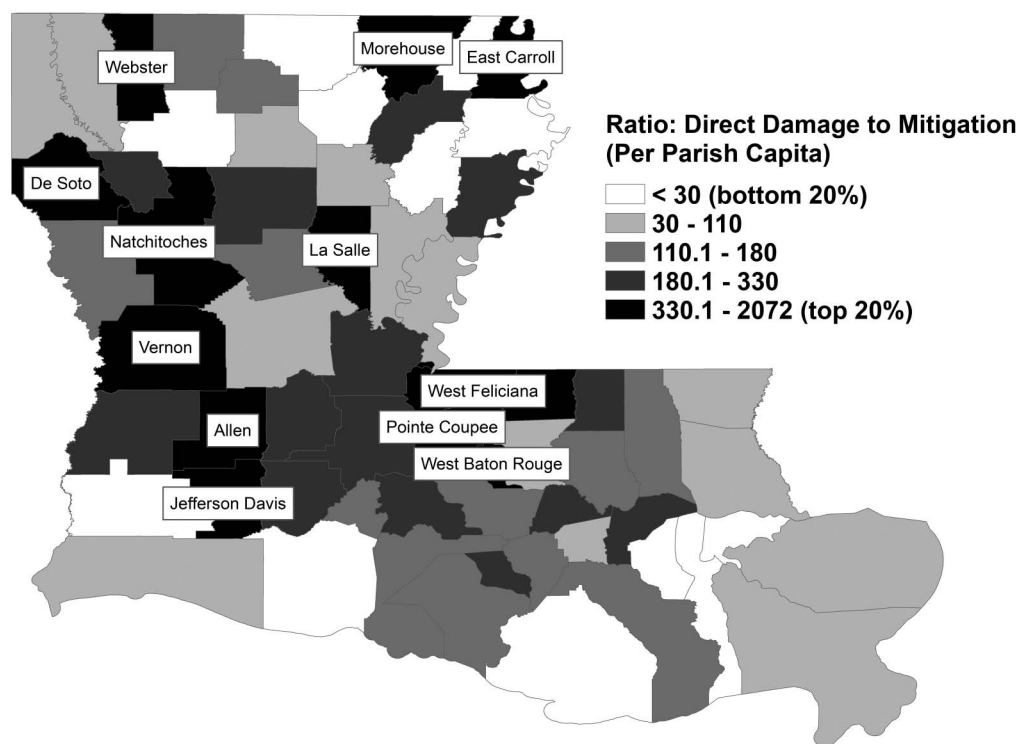


(a)

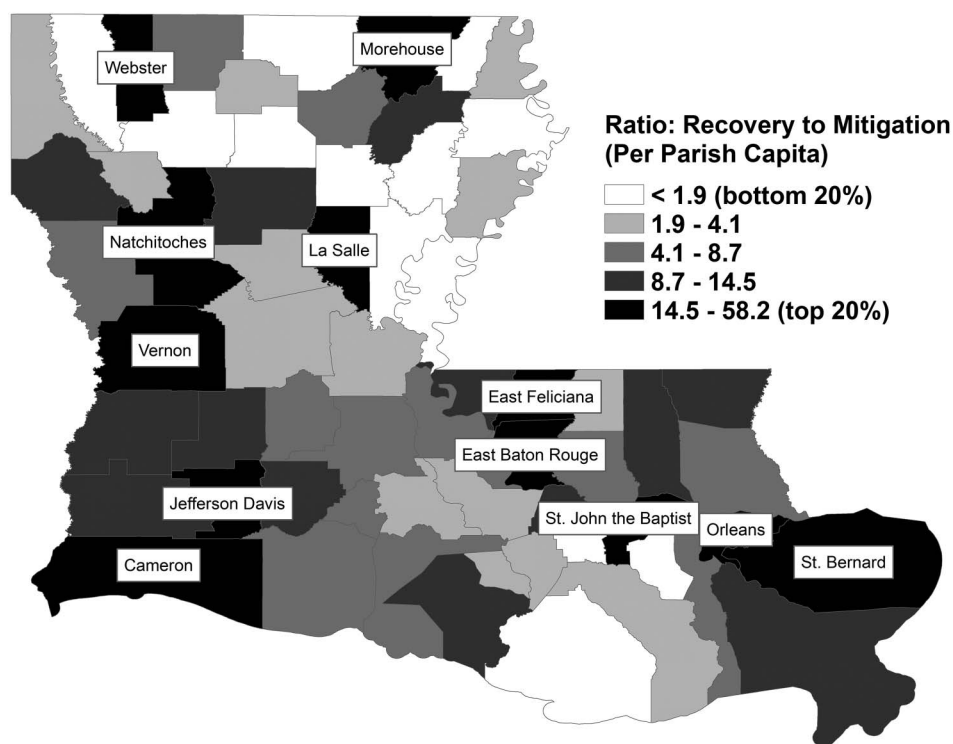


(b)

Fig. 4. Mapped totals of (a) damage; and (b) mitigation; as well as (c) per parish capita ratios of damage to mitigation; and (d) recovery to mitigation expenditures by parish. Only parishes with the highest losses, mitigation funding, and ratios are labeled. All maps show a quantile classification with each class representing 20% of the parishes.



(c)



(d)

Fig. 4. (Continued.)

2005 record-setting damage values, the trend remains positive albeit with a less steep incline (slope of trend line drops from 1,665 to 46). Mitigation investments since 1989 have not had a measurable effect on the damage trajectory of the state. While individual mitigation projects will have avoided losses, the total investments

in hazard mitigation have neither stabilized nor reduced direct damage from natural hazards as a whole. The results of this study do not suggest that mitigation is ineffective in avoiding losses and saving lives, but rather that mitigation investments are insufficient to stabilize ever-rising direct damage, let alone indirect damage.

Table 4. Direct damage, mitigation, and recovery expenditures expressed as totals, per parish capita, and ratios for Louisiana parishes

Parish	Direct damage		Mitigation expenditures		Recovery expenditures		Per parish capita ratios		
	Total	Per parish capita	Total	Per parish capita	Total	Per parish capita	Direct damage to recovery expenditures (DRR)	Direct damage to mitigation expenditures (DMR)	Recovery to mitigation expenditures (RMR)
Acadia	\$1,153,165,250	\$19,629	\$3,851,262	\$65	\$45,095,005	\$753	26.1	302.5	11.61
Allen	\$558,223,401	\$23,386	\$1,778,089	\$71	\$17,472,414	\$698	33.5	330.4	9.87
Ascension	\$3,022,364,173	\$32,860	\$12,276,230	\$133	\$163,262,406	\$1,442	22.8	246.5	10.82
Assumption	\$1,405,292,320	\$62,529	\$11,122,440	\$484	\$22,946,067	\$999	62.6	129.1	2.06
Avoyelles	\$614,489,700	\$15,026	\$2,412,404	\$58	\$8,978,376	\$213	70.5	259.4	3.68
Beauregard	\$597,860,468	\$18,983	\$2,478,293	\$73	\$34,508,700	\$1,002	18.9	261.8	13.82
Bienville	\$120,358,047	\$7,444	\$9,426,535	\$628	\$1,361,157	\$97	76.4	11.9	0.16
Bossier	\$383,521,404	\$4,871	\$7,460,594	\$70	\$15,747,599	\$136	35.9	69.8	1.94
Caddo	\$404,176,954	\$1,642	\$4,271,324	\$17	\$11,537,463	\$46	35.6	94.0	2.64
Calcasieu	\$818,852,001	\$4,605	\$36,570,536	\$197	\$432,151,349	\$2,341	2.0	23.3	11.86
Caldwell	\$102,518,735	\$10,805	\$3,687,712	\$354	\$3,727,635	\$363	29.8	30.5	1.02
Cameron	\$695,468,871	\$80,835	\$16,652,665	\$1,810	\$335,671,572	\$37,773	2.1	44.7	20.86
Catahoula	\$121,216,377	\$10,708	\$2,561,091	\$242	\$3,304,837	\$317	33.7	44.2	1.31
Claiborne	\$122,981,384	\$6,961	\$673,924	\$41	\$3,243,121	\$196	35.5	168.8	4.75
Concordia	\$113,352,302	\$5,392	\$2,555,082	\$135	\$4,708,601	\$238	22.6	39.9	1.76
DeSoto	\$127,718,006	\$5,186	\$183,252	\$7	\$2,726,116	\$102	50.7	734.5	14.49
East Baton Rouge	\$3,932,078,531	\$9,309	\$45,957,372	\$111	\$2,700,795,526	\$6,446	1.4	84.0	58.19
East Carroll	\$919,440,086	\$109,467	\$1,912,186	\$225	\$3,543,282	\$441	248.2	486.3	1.96
East Feliciana	\$1,462,650,845	\$72,216	\$716,382	\$35	\$20,619,752	\$1,009	71.6	2,072.0	28.95
Evangeline	\$698,409,926	\$20,201	\$2,718,494	\$77	\$15,477,191	\$443	45.6	262.5	5.75
Franklin	\$131,258,614	\$5,678	\$8,410,556	\$418	\$9,132,307	\$456	12.4	13.6	1.09
Grant	\$85,106,585	\$6,091	\$1,045,562	\$54	\$4,234,055	\$203	30.1	112.7	3.75
Iberia	\$1,131,776,077	\$15,932	\$10,279,777	\$138	\$78,977,968	\$1,069	14.9	115.5	7.75
Iberville	\$1,488,607,129	\$46,840	\$11,097,423	\$339	\$38,141,016	\$1,164	40.2	138.2	3.43
Jackson	\$100,593,848	\$6,364	\$1,153,917	\$77	\$1,554,480	\$99	64.3	83.0	1.29
Jefferson	\$8,198,850,978	\$18,321	\$329,563,107	\$738	\$2,222,356,118	\$4,928	3.7	24.8	6.67
Jefferson Davis	\$731,563,476	\$23,632	\$2,009,579	\$65	\$32,876,595	\$1,062	22.2	363.5	16.34
LaSalle	\$112,487,556	\$8,304	\$60,879	\$4	\$1,563,354	\$109	76.4	1,894.3	24.79
Lafayette	\$2,117,064,154	\$10,302	\$16,782,167	\$82	\$101,305,731	\$472	21.8	125.2	5.74
Lafourche	\$8,066,393,435	\$89,042	\$52,274,892	\$575	\$117,184,894	\$1,265	70.4	154.9	2.20
Lincoln	\$122,111,957	\$3,476	\$1,208,410	\$28	\$3,027,155	\$69	50.4	122.7	2.44
Livingston	\$3,548,677,847	\$33,069	\$35,349,036	\$300	\$352,208,313	\$2,616	12.6	110.1	8.71
Madison	\$189,482,346	\$14,025	\$6,692,268	\$554	\$1,525,213	\$130	108.1	25.3	0.23
Morehouse	\$174,232,071	\$5,483	\$270,074	\$9	\$7,075,351	\$264	20.8	597.3	28.74
Natchitoches	\$125,859,224	\$3,428	\$264,424	\$7	\$13,124,581	\$336	10.2	502.8	49.30
Orleans	\$8,098,020,645	\$17,759	\$274,464,949	\$605	\$9,631,878,098	\$21,215	0.8	29.4	35.08
Ouachita	\$252,458,091	\$1,893	\$9,822,619	\$67	\$50,487,738	\$325	5.8	28.3	4.86
Plaquemines	\$8,078,932,017	\$285,639	\$104,774,536	\$3,851	\$1,289,374,532	\$46,170	6.2	74.2	11.99
Pointe Coupee	\$1,457,686,954	\$65,817	\$3,682,290	\$167	\$24,217,397	\$1,080	60.9	393.5	6.46
Rapides	\$657,018,348	\$5,161	\$12,248,937	\$92	\$25,743,146	\$195	26.5	56.0	2.12
Red River	\$102,476,636	\$10,647	\$425,157	\$46	\$865,243	\$99	107.2	230.5	2.15
Richland	\$144,910,267	\$6,671	\$644,699	\$32	\$8,112,385	\$397	16.8	211.1	12.55
Sabine	\$102,162,224	\$5,158	\$1,043,878	\$45	\$6,306,647	\$267	19.3	115.6	5.99
St. Bernard	\$8,044,422,705	\$127,227	\$74,871,448	\$1,160	\$2,687,109,773	\$41,498	3.1	109.7	35.77
St. Charles	\$1,513,885,449	\$37,049	\$62,774,843	\$1,239	\$84,720,814	\$1,678	22.1	29.9	1.35
St. Helena	\$1,466,074,563	\$155,676	\$4,966,077	\$485	\$15,920,234	\$1,524	102.1	320.8	3.14
St. James	\$1,436,375,701	\$76,044	\$15,971,943	\$769	\$27,569,884	\$1,313	57.9	98.9	1.71
St. John the Baptist	\$1,660,035,137	\$45,354	\$9,457,561	\$201	\$144,174,960	\$3,185	14.2	225.5	15.83
St. Landry	\$781,397,931	\$10,336	\$5,144,042	\$57	\$43,431,976	\$488	21.2	180.7	8.53
St. Martin	\$1,250,238,188	\$30,541	\$7,534,956	\$149	\$24,923,947	\$482	63.4	205.0	3.23
St. Mary	\$936,008,640	\$19,396	\$7,444,062	\$146	\$72,359,242	\$1,399	13.9	132.9	9.58
St. Tammany	\$8,205,909,461	\$41,894	\$167,296,720	\$775	\$1,142,823,335	\$5,234	8.0	54.1	6.75
Tangipahoa	\$2,654,101,727	\$24,536	\$20,456,456	\$176	\$189,332,335	\$1,639	15.0	139.1	9.29
Tensas	\$133,327,326	\$16,549	\$416,716	\$71	\$1,647,457	\$293	56.4	233.0	4.13
Terrebonne	\$1,548,696,581	\$15,350	\$122,102,814	\$1,135	\$189,705,875	\$1,757	8.7	13.5	1.55
Union	\$125,093,749	\$6,398	\$8,152,378	\$359	\$6,506,760	\$289	22.1	17.8	0.80
Vermilion	\$908,143,305	\$17,200	\$31,457,633	\$580	\$139,113,078	\$2,511	6.8	29.7	4.33
Vernon	\$484,561,796	\$10,233	\$1,529,001	\$30	\$25,223,553	\$504	20.3	335.8	16.54
Washington	\$1,469,914,166	\$33,597	\$16,935,346	\$384	\$211,073,771	\$4,791	7.0	87.5	12.47
Webster	\$117,980,261	\$2,901	\$200,556	\$5	\$7,458,390	\$186	15.6	594.7	38.10
West Baton Rouge	\$1,474,507,198	\$79,361	\$2,752,011	\$125	\$11,889,231	\$528	150.2	635.5	4.23

Table 4. (Continued.)

Parish	Direct damage		Mitigation expenditures		Recovery expenditures		Per parish capita ratios		
	Total	Per parish capita	Total	Per parish capita	Total	Per parish capita	Direct damage to recovery expenditures (DRR)	Direct damage to mitigation expenditures (DMR)	Recovery to mitigation expenditures (RMR)
West Carroll	\$119,617,711	\$9,252	\$4,098,323	\$347	\$3,001,566	\$267	34.7	26.6	0.77
West Feliciana	\$1,440,148,767	\$101,705	\$984,355	\$66	\$13,774,984	\$905	112.4	1,552.7	13.81
Winn	\$101,837,156	\$6,231	\$297,283	\$19	\$4,046,464	\$273	22.9	329.4	14.41
Statewide			\$1,290,939,508	\$287					
Total	\$98,464,146,781		\$2,908,619,035		\$46,697,907,524				
Average		\$32,463		\$334		\$3,278	39.2	258.9	10.3

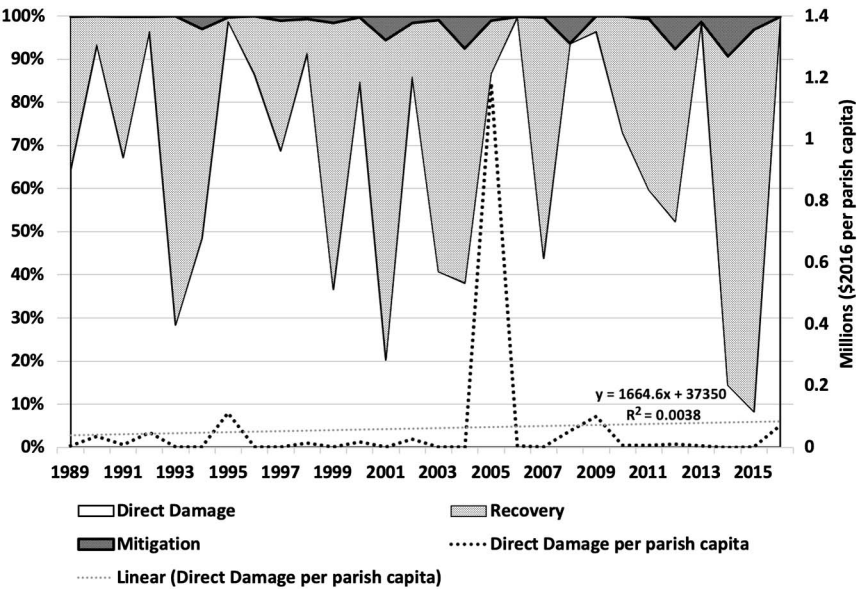


Fig. 5. Temporal trends in damage costs, recovery spending, and mitigation investments (per parish capita). The left y-axis shows the annual share of damage, recovery, and mitigation funds. Please note that there are time lags between damage, recovery, and mitigation spending due to availability of funding, project application/approval, multiyear construction projects, etc. Mitigation funds are dispersed at least 1 year after the event. The right y-axis represents direct damage (per parish capita) over time. The damage trend when controlling for inflation and population is upward.

Performance Metrics: Ratios Reveal Relationship between Damage, Recovery, and Mitigation

Damage to Recovery

The average per parish capita ratio of direct damage to recovery expenditures is \$39:1 across Louisiana. In other words, for every \$39 in damage per parish capita, parish residents receive \$1 in recovery funds (Table 4). Parishes with the highest ratio of damage to recovery expenditures are East Carroll (\$248:1), West Baton Rouge (\$150:1), West Feliciana (\$112:1), Madison (\$108:1), and Red River (\$107:1). Meanwhile, parishes with the lowest ratio of damage to recovery expenditures are Orleans and East Baton Rouge (\$1:1), Calcasieu and Cameron (\$2:1), and St. Bernard (\$3:1). Thus, the most populous parishes tend to receive as much in recovery funding as they experience in damage.

Damage to Mitigation

The state incurred on average \$259 in damage (per parish capita) for every \$1 spent on mitigation (Table 4) with noncoastal parishes receiving the least amount of mitigation funding in comparison to the amount of damage received [Fig. 4(c)]. Parishes with the

highest ratio of damage to mitigation expenditures are East Feliciana (\$2,072:1), LaSalle (\$1,894:1), West Feliciana (\$1,553:1), DeSoto (\$735:1), and West Baton Rouge (\$636:1). Meanwhile, parishes with the highest ratio of damage to mitigation expenditures are: Bienville (\$12:1), Terrebonne and Franklin (\$14:1), Union (\$18:1), and Calcasieu (\$23:1).

Recovery to Mitigation

Similarly, for every \$10 in recovery (per parish capita), only \$1 is invested in mitigation. This gap is especially drastic in the most populous parishes such as East Baton Rouge Parish (\$58:1) and in Orleans Parish (\$35:1), along with less populous parishes such as Natchitoches (\$49:1), Webster (\$38:1), and St. Bernard (\$36:1). Parishes with the lowest ratio of recovery to mitigation expenditures are Bienville and Madison (close to \$0:1), and West Carroll, Union, and Caldwell (\$1:1) [Fig. 4(d)].

Discussion

After the exploratory data analysis of direct damage, recovery costs, and mitigation expenditures, it is clear that Louisiana's

disaster damage and recovery expenditures exceed mitigation investments by at least one order of magnitude. Perhaps the nearly \$3 billion mitigation investment in Louisiana will return \$18 billion in loss reduction in the future as suggested by MMC (2017). However, given the +\$98 billion in direct losses since 1960, significantly more mitigation actions (and investments) are needed to offset escalating disaster losses.

It is doubtful that federal mitigation funds will become available at a scale needed in Louisiana. Instead, changes to the current system of mitigation funding seem inevitable and necessary to achieve meaningful, long-term mitigation rather than funding recovery activities under the guise of mitigation. Dwindling federal resources combined with future risks, especially along the coast, are likely to hasten a retooling of mitigation funding and postdisaster recovery funding (Kousky and Shabman 2017). Ideas exist, for example, homeowner mitigation loan programs (H.R. 1239), tax credit for mitigation expenditures (H.R. 308), and establishment of a National Hurricane Research Initiative to improve hurricane preparedness (H.R. 327) (CRS 2009).

Research shows though that the role of the federal government may be not as important as state and local leadership in creating more resilient communities, as state policies are much more likely to positively affect local resilience strategies than federal policies (Berke et al. 1996, 2014). Despite the demonstrated reduction in hazard losses from stronger building codes (Done et al. 2018), adopting stronger codes in Louisiana remains a contentious topic, marked by extensive lobbying from builders and developers, similar to recent trends in Florida (Flavelle 2018; IBHS 2018). For example, the 2018 Louisiana State Uniform Construction Code deleted the 2015 International Residential Code (IRC) requirements to add 0.3 m (1 ft) of freeboard (i.e., additional elevation) above the 1% annual probability of exceedance (APE) flood elevation in Coastal A Zones, AO Zones, and for basement floors and enclosed areas below the design flood elevation [La. Admin. Code 17:107 (2018)].

As a state, Louisiana does not appear to be committed to mitigating flood damage at the time of construction by implementing and enforcing higher statewide freeboard standards. Instead, the state has relied on elevating existing buildings or buyouts. This is an extremely ineffective and expensive way to mitigate buildings against flood hazards. Elevating existing homes after a disaster will be financially unsustainable given foreseeable changes to sea levels, storm frequencies, and intensities (Emanuel 2017). It is common sense that “(r)etroactively altering a home, and realistically entire neighborhoods, to conform to new building codes is economically prohibitive and politically infeasible” (Davlasheridze et al. 2017; Highfield et al. 2014, p. 298). Perhaps the cost of additional elevation at the time of construction may be better borne by homeowners or incentivized through state-level programs, rather than by the federal government, as there are (at a minimum) insurance incentives for including mitigation features in building construction that can be captured by the owner.

To curb disaster damage, Louisiana must utilize the entire suite of mitigation actions, not just those fundable through federal mitigation programs. This includes, first and foremost, land use planning, zoning, and stronger building codes. These changes will not be easy and will require local leadership combined with education of and outreach to planners, public officials, and residents. State and local leaders and building code councils must critically review and understand the consequences of adhering to existing standards, as well as advocating for changes that increase community resilience and decrease losses, such as those that exceed the 2015 I-codes evaluated by MMC (2017). Homeowners, new and old, need to learn where to build, how to build, and what to look for

in a property when it comes to hazard-resilient construction. Incentives such as tax deductions for home upgrades, and so forth, could accelerate the upgrade of the existing building stock and alleviate the financial burden for homeowners.

Louisiana municipalities should also become more active and improve their CRS ratings to not only mitigate flood risk but to also garner flood insurance discounts for their residents. Few communities are rated in Class 6 (FEMA 2016a), meaning their residents save 20% on flood insurance premiums. Given that flood insurance is required for homeowners as a condition of financing and that much of the state is at risk from flooding, discounted flood insurance premiums should be a top priority for local officials. Unfortunately, the high number of repetitive loss and severe repetitive loss properties makes it exceedingly difficult for Louisiana municipalities to achieve a higher CRS class.

The overarching objectives must become to stabilize or reduce damage through all types of mitigation actions and to reduce the damage to mitigation ratio. This includes a more strategic approach to hazard mitigation, less driven by federal mitigation funding, that engages sustainable practices and limits investments in cost-prohibitive activities such as property elevation postconstruction. Otherwise, the state’s residents will remain in a perpetual cycle of damage and recovery without tangible benefits from hazard mitigation.

Study Limitations and Next Steps

Klotzbach et al. (2018) argue that increases in wealth (i.e., more assets at risk) alone account for escalating disaster damage, and that there is no observable increase in hurricane frequency or occurrence. In contrast, Gall et al. (2011) found that even when accounting for growth in population and wealth, disaster losses are increasing across the United States at the state level. While the scientific discussion is not settled, outcomes (i.e., higher losses) are agreed upon. What is often overlooked, however, is the accuracy of damage estimates, which tend to be notoriously underreported (Gall et al. 2009). Thus, damage figures and damage ratios provided in this study are conservative, meaning that the gap between damage and mitigation investments is likely larger.

In addition, this study does not account for fatalities and injuries, including long-term mental health effects (e.g., post-traumatic stress disorders). As mentioned previously, recovery expenditures exclude a whole suite of common expenditures such as wind insurance payouts, business interruptions, lost wages, and more. Thus, damage from natural hazards (direct, indirect, insured, and uninsured) as well as recovery figures are likely to be much higher. Data on the mitigation investments, on the other hand, are fairly accurate given that FEMA tracks mitigation project costs and that there are no separate state or local-level mitigation programs or incentives in the case of Louisiana. This means that the proposed performance metrics (damage to mitigation ratios and recovery to mitigation ratios) are too generous, meaning the relative share of mitigation investments may be miniscule when fully accounting for damage and recovery.

This study is solely of exploratory nature. The authors refrained from performing time series or (spatial) regression analysis not only because of the aforementioned data limitations, but also because of the difficulties in allocating recovery and mitigation investments over time. Future research is needed that directly ties mitigation expenditures and the type of mitigation projects related to a specific disaster and/or hazard type.

How to best utilize the damage to mitigation and recovery to mitigation ratios as performance metrics remains to be further

explored, ideally in an integrated manner with practitioners and planners to also test their utility. For example, Cameron Parish, which was devastated by Hurricane Rita, saw double the damage compared to recovery expenditures but only received \$1 in mitigation investment for every \$21 in recovery funds spent. On the other hand, Plaquemines Parish had more than six times the damage compared to recovery expenditures but received \$1 in mitigation investment for every \$12 in recovery funds spent. While the value of this research lies in its contextualization of mitigation investments with regard to damage and recovery costs, this paper cannot answer the question if it is better to invest more heavily into recovery, mitigation, or both in terms of long-term loss reduction.

Research on hazard mitigation should look beyond mitigation projects and respective avoided losses. By focusing on benefit-cost-analysis, the network of mitigation projects is not taken into consideration—their knock-on, or cumulative effects (intended or unintended) over space and time. What is also not taken into consideration is (1) the relationship to damage or recovery costs (i.e., how much damage a community must absorb before receiving federal mitigation dollars) and (2) the ability of mitigation investments to make a difference (i.e., to stabilize or reduce disaster damage).

Project-level research should explore if there is differential benefit and costs in terms of the timing of mitigation actions. That is, is implementation better postdisaster or predisaster? Additional study is also warranted to determine if the cost of building an elevated foundation (e.g., pier and beam) exceeds the cost of building a slab foundation and if so, by how much. It may be found that elevating at the time of construction actually represents significant savings considering the costs of construction and flood insurance savings alone, in addition to a lifetime of reduced flood risk for the building. This type of research would provide owners and community officials with actionable information about building/mitigation attributes and the building lifecycle cost impacts of mitigation as the basis for building code reform and/or improved owner decision making.

Conclusions

This study found that the State of Louisiana relies heavily on HMGP funds and a select few mitigation actions (e.g., property elevation and acquisition). For every mitigation dollar invested in a parish, residents experience nearly \$260 in damage and see only \$10 in federal recovery funds flow into the parish. Past mitigation investments, while avoiding losses, are insufficient and have not stabilized the damage trajectory of the state. Significant investments, programs, and activities engaging the whole community need to be implemented to build more resilient communities and reduce losses.

Louisiana (and many other states) need to view hazard mitigation planning not as a compliance exercise with mitigation grant programs, but must integrate mitigation into comprehensive community planning and devise state programs that help and incentivize local municipalities and residents to invest. Hazard mitigation must become an inherent, long-term strategy of every municipality's strategic development plan using every tool in the mitigation toolbox and must become less reliant on the availability of federal funding. The recent Master Plan for the Coast (CPRA 2017) is unequivocal: land loss and sea-level rise are outpacing wetland restoration. Communities must begin to think seriously about future land use, zoning, and building codes. Being more strategic in terms of the types and locations for implementation of mitigation actions will become exceedingly more important as climate change

increases risk and exposure levels. Federal disaster funds are a finite resource and FEMA's (draft) Mitigation Investment Strategy is calling for financial support from private and nonprofit partners to shore up hazard mitigation investments, which the federal government alone cannot shoulder.

The time has come where residents can no longer be put in harm's way for local tax gains. It is the responsibility of local officials to keep their residents safe by requiring better construction practices and standards while investing mitigation funds strategically and effectively in both structural and nonstructural activities. This cannot mean relaxing building codes or rolling back building codes postdisaster to speed up recovery. Residences and public infrastructure must be able to withstand the hazards facing Louisiana, both for the next disaster and the new normal brought on by climate change (Kunreuther et al. 2013).

Moving forward, a comprehensive review of the effectiveness of mitigation activities in reducing losses, their co-benefits, and (unintended) consequences are needed nationwide to strategically and most cost-effectively leverage public-private partnership investments. Rethinking and modernizing how mitigation planning occurs and actions are implemented will mature existing approaches and possibly lead to a mainstreaming of mitigation planning and a better integration with community or comprehensive planning. As Wendy Smith Reeves, the Director of Arizona's Division of Emergency Management, stated: it is time for states to show what their investment in hazard mitigation is (Rein 2017).

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