THE ROLE OF WETLANDS IN MITIGATING SOCIAL COSTS OF DISASTERS

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

The Role of Wetlands in Mitigating Social Costs of Disasters

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Social costs associated with disaster recovery in the United States have been on a rise in recent decades given unprecedented number of extreme weather events including floods, coastal storms and hurricanes. Understanding how to proactively manage and mitigate disaster risk has become a priority for many coastal communities. Among many alternatives, nature-based risk management solutions including preservation and restoration of wetlands, mangroves and dunes have been considered increasingly. In this paper, we examine the effectiveness of wetlands in mitigating social costs associated with flooding disasters. Analyzing the data of counties along the Gulf of Mexico coast, we find some empirical evidence that restoring wetlands effectively reduces spending on federal disaster recovery programs. The implication of our research is tremendous given staggering rate of loss of wetlands in the United States and rising number of disasters as well as increasing financial costs of disaster aid.

CHAPTER I

INTRODUCTION

Floods have been reported to be the costliest of natural disasters worldwide (Miller et al., 2008) and affect the most people (Stromberg, 2007). This is also the case in the United States as out of all natural disasters, floods accounted for the most lives lost and the highest amount of property damage at $179 billion since 1900 (Perry, 2000; Constanza 2008). Coastal communities have experienced increasing populations as there are many allures for settlement as they provide coastal amenities and jobs. However, the population and wealth exposure raises a concern of how to sustainably mitigate the damages of these increasingly frequent and intense disasters. One strategy is to integrate ecosystems in disaster risk mitigation and lessen disaster impact. Some important ecosystem in this aspect are mangroves, vegetative dunes and slopes, forests to sequester carbon to reduces risks of climate change, and wetlands (Kousky, 2010).

Despite the number of ecological and economic benefits the wetlands provide, this important ecosystem has been threatened worldwide (Barbier, 1997). The United States alone has lost 50-85% of wetlands during the 1950-1970 and still continues to lose annually at an estimated rate of 70,000 to 90,000 acres (Dahl and Johnson, 1991; Dahl, 1990). Historically, primary causes of physical loss of wetland acreage have been due to its conversion to agricultural and urban uses (Maltby, 1986), with saltwater systems experiencing 99% of all loss from open ocean generated processes such as saltwater inundation, sea level rise and coastal storms (Dahl, 2009).Wetlands are known for their buffering affect against storms as they offer flood storage, enhance water quality, as well as protect against wave action and shoreline erosion (Barbier, 1994). Such a staggering decline of wetlands has detrimental implication not only for marine ecosystem and resources they support, but also increase the vulnerability of coastal communities to flooding, surge events and hurricanes.

This project aims to estimate the effectiveness of coastal wetlands in mitigating disaster recovery spending post-event. Limited empirical research indicates that altering wetlands leads to increased losses from floods (Brody et al., 2011; Highfield et al. 2018), however flood mitigating effects of wetlands appear to depend on the type of wetland (Brody et al, 2011). Prior studies at hurricane swath level also show that the wetlands significantly mitigate hurricane-induced damages in the United States (USACE, 1963; Costanza et al, 2008). Overall, no prior study has examined the effects of wetlands, as *ex ante* mitigation strategy, on reducing social costs of disasters, i.e. *ex post* disaster recovery spending. Understanding whether and by how much, the local mitigation policy that entails wetland preservation, restoration and creation can save federal money on disaster programs is important for disaster mitigation policy making.

Literature Review

Disaster Declaration and Federal Disaster Management

Disaster declaration in the United States is stipulated as part of the Robert T Stafford Disaster Relief and Emergency Assistance Act of 1988. The Act grants the president a sole discretion to declare a major disaster or emergency, in response to the state governor's request to assist in local recovery efforts in the aftermath of a major incident. Disaster declaration itself triggers the allocation of federal disaster aids across multiple projects managed by Federal Emergency Management Agency (FEMA). The FEMA disaster assistance is provided through the Disaster Relief Fund (DRF) (McCarthy, 2011; Lindsay and McCarthy, 2012; Lindsay, 2014) and funds a variety of projects including the care of disaster survivors, restoration of damaged facilities, debris removal, aid for uninsured victims with critical needs, and investment in long-term mitigation measures to prevent future disaster impacts (Bea, 2005). In addition to a direct cash aid and post-disaster assistance for public projects, the FEMA also provides unemployment assistance for affected individuals and business for jobs and revenue losses.

Among the federally funded disaster programs, the Public Assistance (PA) program is largest and is available to states and local governmental and specific private nonprofit (PNP) organizations to address disaster consequences, in response to a major Presidential Disaster Declaration (PDD). There are two types of activities funded by the PA program: Emergency Works and Permanent Works projects. The former provides grants for emergency protective measures, debris removal and clean-up projects, and the latter funds permanent restoration of damaged facilities, restoration and rehabilitation of roads, bridges and other critical infrastructure, water control facilities, public buildings and equipment, utilities, and parks, recreational and other facilities.

The funds are given on a cost-share basis, federal share commonly determined at less than 75% of the eligible cost for emergency measures and permanent restoration, and the non-federal share corresponds to 25%, which is shared by relevant local stakeholders (state and eligible applicants or subrecepients).

The PA eligibility determination is a lengthy process and involves a four-tiered process including the applicant's eligibility and facility eligibility determination, evaluation of work, and eligibility of costs claimed by the applicant. The timeline of PA grants available involves multiple phases starting with preliminary damage assessment followed by the submission of a declaration request by the state/territory/tribe and ultimately the presidential declaration, collaboration with the applicant, subaward formulation, and ending with subaward funding typically within 30 days of the application (FEMA, 2018).

Past research has shown that post-disaster recovery funds are beneficial for two primary reasons: (1) it is more cost effective to include hazard mitigation into rebuilding rather than changing existing structures before the incident, and (2) affected communities are more engaged in risk reduction post disaster. However, the allocation of these funds are exclusively for disaster-affected communities, but not for the areas that face the greatest risk of future coastal disasters. Furthermore, projects are not scrutinized rigorously and money is spent in a post-disaster chaotic environment, which could lead to further inefficiency (Kousky & Shabman, 2017). Past research has indicated both the recovery and long-mitigation programs of FEMA to be effective in mitigating direct disaster damages, however the former projects have shown to be twice as effective despite being disproportionately underfunded (Davlasheridze, Fisher-Vanden and Klaiber, 2017).

One important aspect to note is that while the magnitude of impacts is a primarily driver of the disaster declaration by the president, the past research has also suggested disaster declaration and aid allocation to be politically motivated. For example, Garett and Sobel (2003) have shown that higher rates of disaster declaration are given to states that are politically important to the president, with a higher mean level of declaration during election years. This can have significant implications on both of the timing as well as the amount of funds dispersed across impacted communities. In figure 1 we show the amount of PA payments from flood damages per coastal county from 2012-2017.

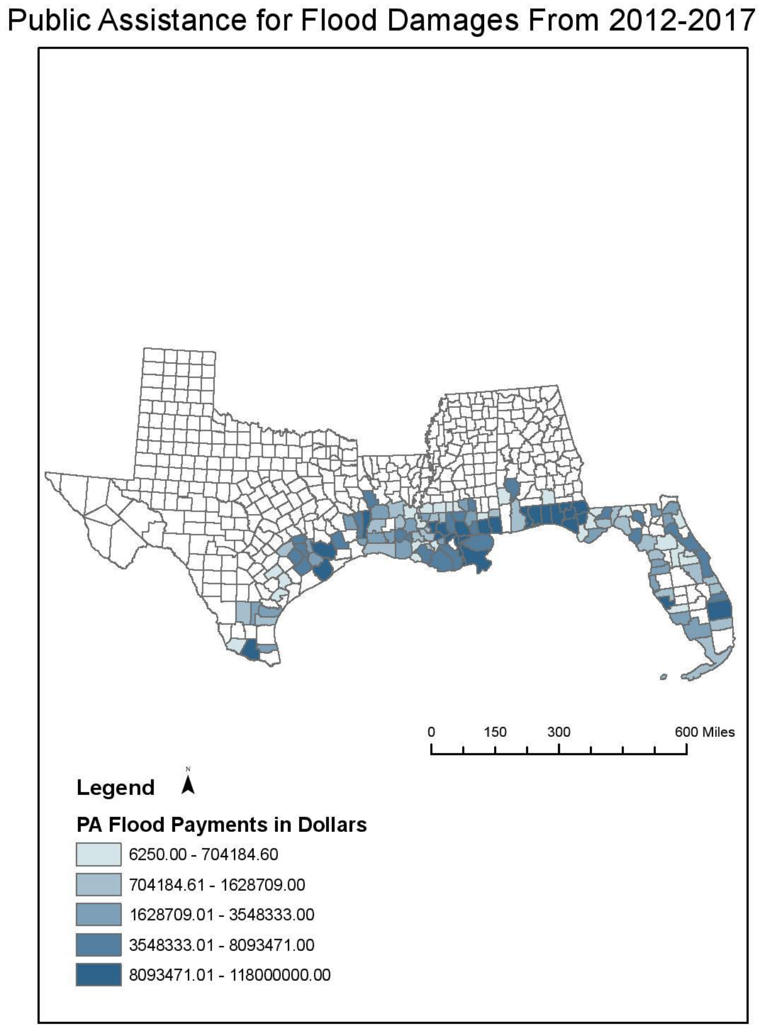

Figure 1. Public assistance payments for flood damages from 2012-2017. Source: FEMA

Wetland Values

Wetlands represent transitional ecosystem between land and water and are defined as areas inundated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil (EPA, 2019). wetlands are one of the most economically and ecologically valuable ecosystems on the planet (Costanza, 1997). Some of the major values of wetlands can be summarized as follows: they provide habitat and nursery grounds for commercially important species, carbon sequestering, flood control, storm buffering, shoreline erosion prevention, nutrient purification and improve water quality, high rates of plant productivity, and are places for recreation, education, and wildlife observation (Engle, 2011).

Serving as habitat is perhaps one of the most valuable functions as wetlands provide nursery grounds for commercial fish species, recreational fishing and hunting services, in addition to increasing overall biodiversity associated with healthy ecosystems. Together, these services are valued at $912 per hectare annually with commercial fishing providing $778 and recreational fishing providing $357 benefits per acre of wetland (Schuyet & Brander, 2004). Other recreational economic benefits come from bird watching and bird hunting valued at $1212/acre and $778/acre respectively (Woodward & Wui, 2000). Overall, the aggregate recreational value of wetlands is estimated at approximately $118 million annually and the aggregate consumer surplus is estimated at approximately $27 million annually, thus yielding a gross economic value of about $145 million annually (Bergstrom et al., 1990).

Wetlands also provide flood control benefits that have been estimated at $464 per hectare annually (Bergstrom et al., 1990), making them incredibly important ecosystems in buffering against hurricane and storm surge impacts. It has been shown that a 0.1 increase in the wetland to water ratio per meter has the ability to reduce flood damages to residential properties by $99 to $133 (Barbier, 2013). Additionally, since wetlands slow down the flow of water, shoreline erosion is reduced by stabilizing sediments and absorbing and dissipating wave energy (Hammer, 1992). These sediments are valuable as wetland soils are some of the highest carbon storing soils in the world (Nahlik & Fennessy, 2016). While it is difficult to put a dollar value on carbon sequestration wetlands provide, it is estimated that wetlands in the conterminous United States store a total of 11.52 pentagrams of carbon (Nahlik & Fennessy, 2016)

While these ecosystems provide many monetary and ecological benefits, wetland loss is an ongoing issue that is proving to have detrimental effects for coastal communities. The U.S. has lost approximately half of the original 220 million acres prior to European settlement and with it their ecological functions and values have disappeared as well (Hansen et al., 2015). The Gulf of Mexico is a major contributor of wetland values as it contains over half of salt marshes in the US as well as 35% of freshwater wetlands (NFW, 2014). The wetland loss in the Gulf of Mexico (GOM) is accelerating as it has experienced 71% of total wetlands loss in the U.S. over this same time period (NFW, 2014.). There are multiple reasons for such a dramatic decline in wetlands along the GOM coastline. The main cause for woody wetland loss is increased man-made embankments (levees, dams) along the Mississippi delta as a way to contain the river and prevent flooding to adjacent communities that limits sediment transportation to the wetlands surrounding the river. Additionally, canals that have been dredged for shipping and transportation allow intrusion of excess saltwater into wetlands, thus killing the vegetation and causing subsidence of the marsh. The vast majority of losses associated with saltwater systems, i.e., herbaceous wetland types, come from open ocean generated processes such as saltwater inundation, sea level rise and coastal storms (Dahl, 2009). Other reasons for wetland loss include subsidence, agricultural and urban expansion, conversion of forests and uplands, along with direct and indirect human impacts of the area (Boesch et al., 1994).

CHAPTER II

DATA DESCRIPTION

The data used for this study was collected from multiple sources. Our dependent variable is total public assistance (PA) program spending per capita over 2012-2017 period. The data on PA is available publicly from the FEMA. The raw data contained the amount of approved grants by area (i.e., county, city, community), by the PA project activity and the event type. For the purpose of this research, total PA program spending for flooding, storm surge and hurricane incidents were calculated.

As the key variable of interest, we collect the land cover data on wetlands from the National Land Cover Database provided through the Multi-Resolution Land Characteristics Consortium. This data was given in time intervals of 1992, 2001, 2006, and 2011 with multiple land cover types and values. Some land cover types included development level (open space, low, medium, and high intensity), as well as plant type and coverage with classifications such as barren land, lichens, shrub/scrub, dwarf shrub, sedge/herbaceous, grassland, pasture/hay, cultivated crops, deciduous forest, evergreen forest, mixed forest, as well as emergent herbaceous wetlands and woody wetlands. The wetland types are what are examined in this study with emergent herbaceous wetlands being defined as areas where perennial herbaceous vegetation accounts for over 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water, whereas woody wetlands are defined as areas where forest or shrub land vegetation accounts for over 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

To measure the county's experience with extreme precipitation event, we collected the precipitation data from the National Climate Data Center (NCDC) Global Historical Climatology Network (GHCN). The daily precipitation data across weather stations were totaled for each county to derive the annual precipitation measure. Similar to Davlasheridze and Miao (2019) we then calculated the rainfall anomaly variable using the deviation of a county's annual rainfall in 2011 from its long run average precipitation measured during 1950-2000 period, and dividing it by the standard deviation. The positive value of this variable implies excess rainfall in 2011 relative to the long-run average precipitation in a given county.

While the precipitation variable captures the effect of an excess rain which may result in flooding, it does not fully capture the magnitude of impacts. We use the National Flood Insurance Policy (NFIP) data and calculated the total amount of NFIP claims paid by county in 2011, as a proxy for disaster damages. The data on NFIP claims were obtained from the FEMA via the Freedom of Information Act (FOIA).

As for the other control variables, we collected the data on personal income and population from the Bureau of Economic Analysis Regional Economic Account Systems. For each county using the National Flood Hazard Layer provided through FEMA, we have also calculated the total area of 100-year floodplains, which according to FEMA correspond to areas with a 1% annual chance of flooding. Other socio-economic factors considered were poverty and unemployment rates which were obtained from the U.S. Census Bureau and the Bureau of Labor Statistics respectively.

To account for the influence of politics in both the disaster declaration as well as the allocation of FEMA money across impacted communities, we have collected the data from the Dave Leip's Atlas for US Presidential Elections. The data records numbers voting along with the total voter turnout across different presidential candidates during the historic presidential election years. The most recent election for the year 2011 was the 2008 presidential election and we calculated percent voting for the democratic and independent candidate. We assume that the political affiliations and preferences do not change in between the election years.

Table I reports the summary statistics of our main variables. Sample average PA in log terms is 10.90, corresponding to over $4.3 million on PA program spending during 2012-2017 period. Average size of the wetland in the sample is 81.20 acre and the herbaceous type corresponds to 19.57 acres.

Table 1. Summary statistics.

	Mean	Standard Deviation	Min	Max
ln(PA)	10.90	6.26	0	18.58619
Total Wetland Area (acres)	81.20	113.46	.0275769	985.3151
Herbaceous Wetland Area (acres)	19.57	70.04	0	792.2808
Woody Wetland Area (acres)	61.63	67.73	.0040031	667.7259
ln(Income)	10.40	0.19	9.906034	11.0019
Rainfall Anomaly	-0.99	0.85	-2.647448	1.499645
ln(Damage)	4.43	5.66	0	16.59434
Unemployment Rate	9.51	2.59	4.8	19.1
Percent Poverty	21.15	6.56	6	43.2
Percent Vote Independent	0.26	0.23	0	1.44
Percent Vote Democrat	38.87	14.92	13.12	86.88

Floodplain (acres)	131.21	148.25	5.36e-06	1318.323
ln(Population)	10.79	1.27	6.075346	15.24503

Our sample corresponds to the cross-sectional data and covers 379 counties, and 140 coastal counties along the Gulf of Mexico region. According to NOAA (2019), a county is defined as coastal if 1) at least 15 percent of its total land area is located within the Nation's coastal watershed; or 2) a portion of or an entire county accounts for at least 15 percent of a coastal cataloging unit.

CHAPTER III

METHODS

To process the wetland data we have employed the ArcGIS software and for statistical analysis the STATA software was used.

Processing the Spatial Data in ArcGIS

Landcover data were available in a raster format for the years 2001, 2006, and 2011. We processed the wetland data across all these years to analyze the trend in wetland areas across time. The raster data was overlaid with a U.S. county data layer to be able to dissolve all the U.S. data by state using fips codes. Once the dissolve was successful, the selected GOM state(s) (i.e., Texas, Florida, Louisiana, Mississippi, Alabama) were then exported as a new shapefile. We have employed "a clip by raster tool" in order to cut the original raster data into just the GOM states and then into their coastal counties. Additionally, since only wetland values are of primary interest, we selected the appropriate land use covers from the raster clip corresponding to two different types of wetlands, woody and herbaceous (land cover code classifications 90 and 95 respectively). To derive the area of wetlands by county, the tabulate area tool was used on the selected wetland land cover categories. For this research we are primarily focused on herbaceous wetland land cover type (marshes) as these are the areas that are most associated with the coastal environment as woody wetlands are characterized as being farther inland. This is also shown in past studies, such as Costanza et al., 2008, as the woody wetland type did not correlate with hurricane damages whereas herbaceous did.

From this spatial data, we have created maps of the area changes from 2001 to 2006 for herbaceous and total wetland area percent change per coastal county presented in Figures 2 and 3 respectively, as well as the area changes between 2006 to 2011 years (see Figures 4 and 5). The change in from 1992 to 2001 is not presented here as the means of data collection by the USGS has changed in the subsequent time intervals, making the areas incomparable. As shown in the maps, between 2001 and 2006, total wetlands have been in decline across majority of the GOM coastal counties. The counties with access to water have also seen a decline in herbaceous wetland area. From 2006 to 2011, the change (both the growth and decline) in herbaceous wetland area has been smaller in magnitude compared to previous period.

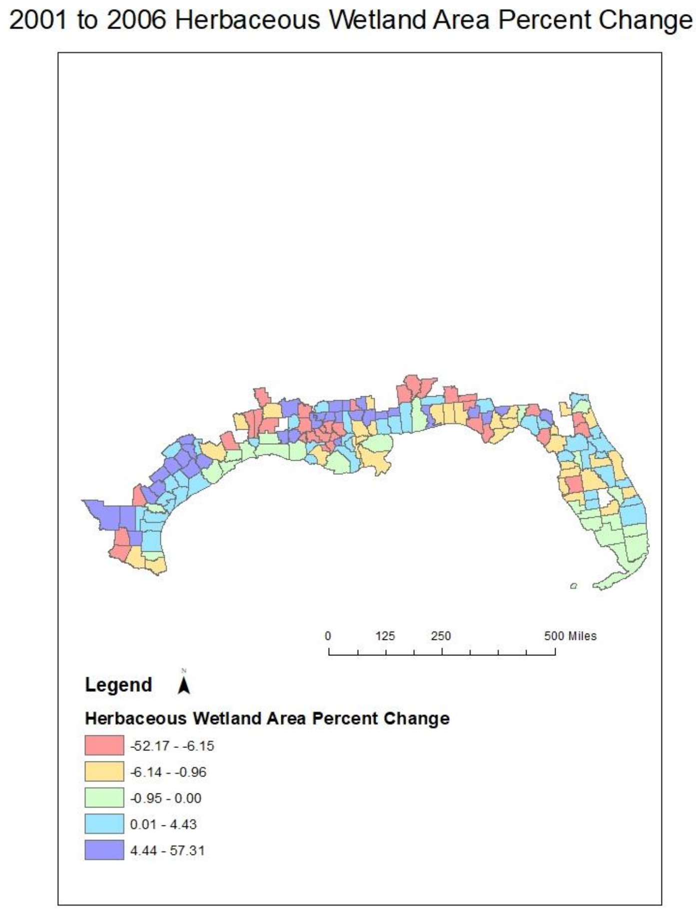

Figure 2. Change in herbaceous wetland area cover per county from 2001 to 2006.

Source: Multi-Resolution Land Characteristics Consortium

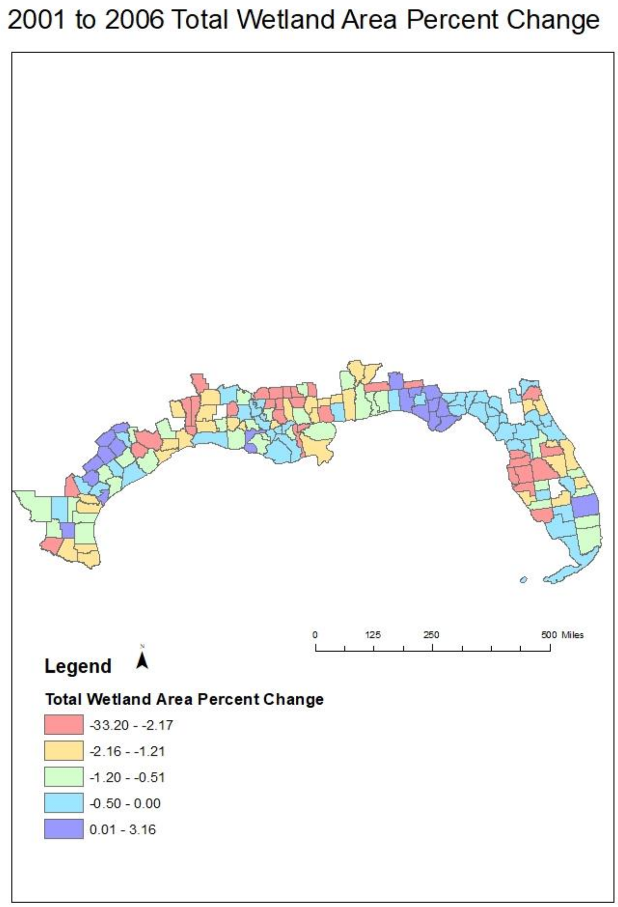

Figure 3. Change in total wetland area cover per county from 2001 to 2006. Source: Multi-Resolution Land Characteristics Consortium

2006 to 2011 Herbaceous Wetland Area Percent Change

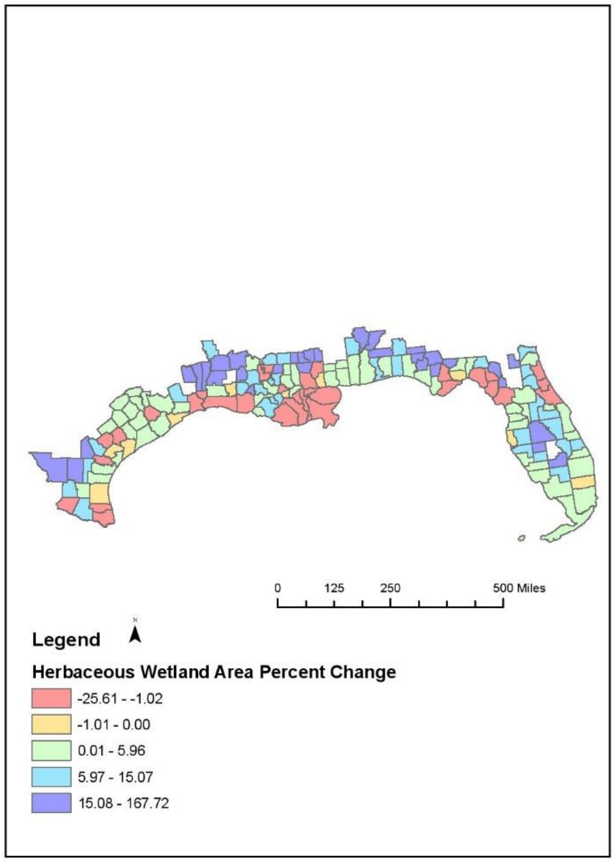

Figure 4. Change in herbaceous wetland area cover per county from 2006 to 2011.

Source: Multi-Resolution Land Characteristics Consortium

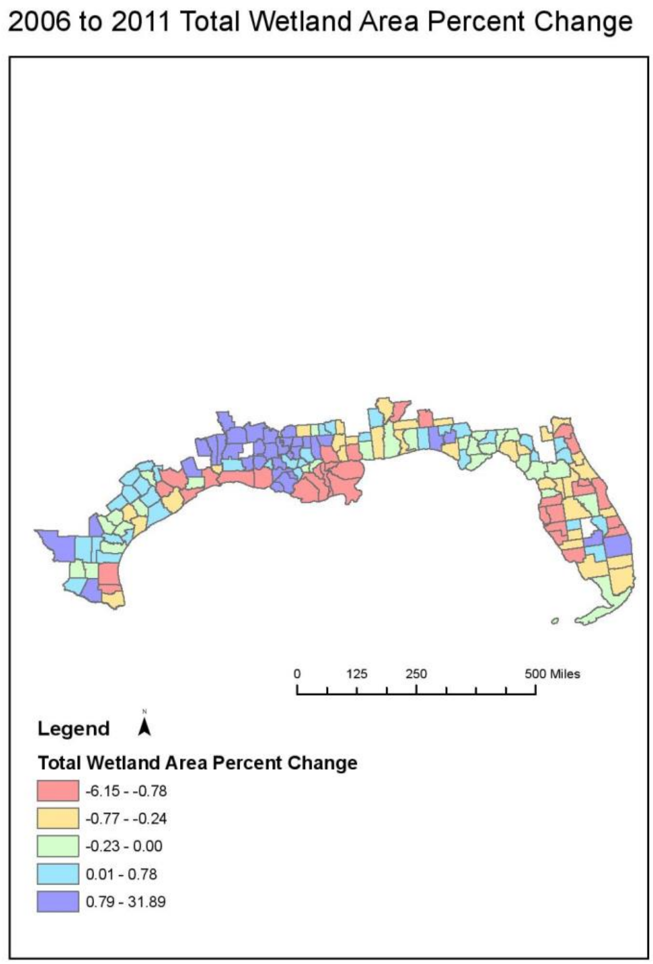

Figure 5. Change in total wetland area cover per county from 2001 to 2006. Source: Multi-Resolution Land Characteristics Consortium

Regression Model

In order to examine the effects of wetlands on the social cost of disasters captured by the FEMA PA spending we estimated a regression model specified in equation (1) as follows:

$$ln\left(\sum_{t=t_0}^{t=T} PA_{it}\right)$$

$$= \beta_0 + \beta_1 Wetlands_{it_0} + \beta_2 Rainfall_{it_0} + +\beta_3 Floodplain_{it_0} + \beta_4 NFIP_{it_0} + \beta_5 \ln(Income_{it_0}) + \beta_6 UnempRate_{it_0} + \beta_7 Poverty_{it_0} + \beta_8 Pct\ Vote\ Ind_{it_0} + \beta_9 Pct\ Vote\ Dem_{it_0} + \beta_{10} Population_{it_0} + e_i$$

The dependent variable, PA_{it} measures cumulative spending of FEMA-approved PA grants related to flooding disasters in a county *i* from year t_0 to T, where $t_0$corresponds to year 2011 and the T equals to 2017. We use the logarithmic transformation of this variable to normalize it. All explanatory variables in this model are measured at the starting year 2011. $Wetlands_{it_0}$is a variable of primary interest and measures the areas of wetlands in acres by the county. The coefficient $\beta_1$associated with this will thus identify the effect of a change in one acre of wetland area on FEMA PA payments over the next 7-year period. $Rainfall_{it_0}$ is the measure of excess rain event in a county i and as discussed in the data section captures proportional deviation of annual rainfall in 2011 from the historical average precipitation. The past research has indicated prior disaster experience could motivate both the individual as well as community level adaptation and mitigation behavior (Sudowski and Sutter, 2008). If this holds true, we expect the coefficient associated with rainfall variable to be negative. The $Floodplain$ measures the total area of 100-year flood zones in acres and captures the baseline level of flood hazard risk. All else held constant, it is expected counties with higher total floodplains to be more prone to flooding hazard and experience higher damages, and subsequent disaster aid. The extend of flood impacts are measured by the NFIP variable, which measures the total dollar amount of NFIP payments in the year 2011.

As for the other socio-economic variables, we measure per capita income for each county in the year 2011, along with the unemployment and poverty rates. All else unchanged, it is expected wealthier counties (i.e, counties with higher income) to have more resources to cope with disaster consequences locally and be less reliant of federal disaster aid. As for the poverty and unemployment, both of these variables capture a county's social vulnerability and lack of local resilience to disasters. We also account for the size of the county including the population numbers (log transformed).

To capture the influence of politics on disaster aid amount, our model specified in equation (1) includes percent voting for the third-party candidate and the percent voting for the democratic candidates during the 2008 presidential election. The percent voting for the republican candidate is an omitted category, hence the coefficients associated with these two are interpreted relative to the omitted category. Finally, e_i denotes the error term, which is assume to be normally distributed with zero mean and the constant variance.

CHAPTER IV

RESULTS

In Appendix Table A1 the Pearson piecewise correlations between explanatory variables are provided. It should be noted that none of the explanatory variables are highly correlated to warrant the multicollinearity problem.

In Table 2 the results from the regression model specified in equation (1) are reported. The column (1) corresponds to the model that includes total area of wetlands as an explanatory variable, whereas column (2) reports results from the model that includes areas of herbaceous wetlands only. As shown in column (1), increasing total area of wetland reduces spending on PA programs, but the relationship is not statistically significant. Focusing on column (2), the significant coefficient ($p<0.05$) associated with herbaceous wetland areas indicate that increasing this type of wetland significantly reduces Public Assistance program spending of FEMA in the subsequent 6 years.

Other variables that indicate significant relationship with PA grants are rain anomalies, percentage of independent and democratic voters, and the population. Specifically, the coefficient associated with the rainfall anomaly is negative, indicating that all else held constant counties experiencing anomalous rainfall event receive less PA funding from subsequent disasters. This is consistent with previous research suggesting that disasters "open windows of opportunities" to rebuild more resilient and that the communities with the experience with large scale disasters tend to experience less damages from subsequent event, indicating greater adaptive capacity by implementing flood mitigating structures (Sadowski and Sutter, 2008). As for the political variables, more independent voters in a county is associated with higher PA program spending relative to the republican (an omitted category), while the opposite holds for counties with larger democratic voters. Increasing PA spending for counties with larger electorate for the third-party candidates is consistent with the past research suggesting that swing counties may receive more disaster aid in exchange of the voters (Garrett and Sobel, 2003). It was estimated that PA grant spending is positively associated with floodplain areas, indicating that counties with higher baseline risk of flood hazard on average receive higher federal disaster aid, relative to the counties with moderate hazard risk. Lastly, the natural log of population indicates that a 1% increase in population, the PA spending increases by approximately 1%, all else held constant.

To estimate the percentage change in PA funding in response to an acre increase in herbaceous wetland areas, we used the following formula:

$$Percent\ Change\ PA = \left(e^{wetlands\ coefficient} - 1\right) * 100$$

using the herbaceous wetlands coefficient (-0.000013) from the column (2) of Table 2, percent change in PA corresponds to 0.0013%, indicating that for every acre increase in herbaceous wetlands, PA spending in the subsequent 6 years is expected to be reduced by 0.0013%. Given that sample average total PA spending over 2012-2017 is $4,303,338, a 0.0013% change corresponds to $55.94 reduction in PA spending per acre of herbaceous wetland increase.

Through NOAA’s Coastal Change Analysis Program (C-CAP) it is estimated that wetland losses in the Gulf of Mexico coastal watersheds were estimated at approximately 256,100 acres from 1996 to 2006 (EPA,2015). The percentage of herbaceous areas from the most recent 2011 dataset make up 23.75% of the total wetland area of the Gulf of Mexico. Using this percentage, it was assumed the same percentage corresponded to herbaceous wetland loss during this period. The loss was estimated at approximately 60,835 acres of herbaceous wetlands. Using the wetland-PA relationship estimated in the regression model, this loss corresponds to an additional $3,403,131 in PA spending for the entire GOM region, or approximately $170,156.60 annually.

Table 2. Regression Results

	(1)	(2)
wetland	-0.000001	-0.000013**
	(0.000005)	(0.000005)
ln_income	-0.776654	-0.285852
	(2.633856)	(2.597164)
rain_ano	-1.695752***	-1.752532***
	(0.491118)	(0.468999)
ln_damage	0.042366	0.053265
	(0.068046)	(0.066685)
unemp_rate	0.194386	0.199225
	(0.177146)	(0.176870)
poverty_pct	-0.008429	-0.022585
	(0.079326)	(0.079154)
vote_ind_pct	3.520594*	4.112459**
	(1.885248)	(1.749229)
vote_dem_pct	-0.059953*	-0.053129*
	(0.031599)	(0.031920)
floodplain	0.000002	0.000005**
	(0.000003)	(0.000002)
ln_pop	1.055297***	1.074974***
	(0.315638)	(0.308442)
_cons	5.265196	-0.470977
	(27.767353)	(27.427696)
R^2	0.09	0.10
N	379	379

Notes: Dependent variable is the log of total PA program spending from 2012-2017 period. Column (1) corresponds to model with the total wetland area, whereas column (2) to the model with herbaceous wetland area; robust standard errors are reported in parenthesis. * $p<0.1$; ** $p<0.05$; *** $p<0.01$

CHAPTER V

CONCLUSION

Floods are the costliest of all natural disasters and concern almost all parts of the United States (Kousky & Shabman, 2017). As the costs and efforts of recovery rise, local communities are overwhelmed as they do not have the capacity and resources to deal with such impacts. This thesis tries to understand how the ecosystem-based approach of risk mitigation can be incorporated in disaster management and combined with traditional risk mitigation alternatives. Our results show that herbaceous wetlands significantly reduce social cost of disasters captured by the FEMA PA spending. This finding is in congruence with Costanza et al., 2008 as their study found that as herbaceous wetland areas decrease by one acre, storm damage increased by $33,000. Barbier et al., 2013 also concluded that wetlands have a considerable effect on reducing storm surge, which is consistent with our finding. Additionally, Farber, 1987 found that loss of wetlands increased the cost of property damage by $7-$23 per acre. Past research has shown that wetlands reduce hurricane impacts and associated damages and costs, however there has been little to no research on how a reduction in wetland areas relates to disaster spending through FEMA PA payments. Not only do wetlands provide flooding mitigation services that affect the size of disaster recovery spending, they also contribute many ecological benefits and values to coastal communities. Bryan & Kandulu (2009) studied at a watershed in South Australia and determined that by including other ecosystem services produced by land-use changes of the area, the project was cost effective.

Despite its significance in buffering storm surge and flood impacts, the preservation and protection of these important resource, have been challenged in many communities at numerous grounds including political opposition, uninterested decision-makers, lack of information and general inertia (Kousky, 2010).

Past research has supported our findings that wetland areas reduce the social costs of disasters as they function as effective storm buffers and provide many additional benefits. This thesis further demonstrates that mitigating herbaceous wetland loss is an important strategy in reducing PA funding in a count, along with the many other ecosystem services they provide. Creating a policy that promotes mitigation and conservation of wetlands along the Gulf of Mexico is an important hazard mitigation strategy and will reduce local reliance on post-disaster recovery aid from the federal government. Such restoration efforts will further enhance the ecological health of the system and promote the overall resilience of coastal communities.

REFERENCES

Barbier EB, Georgiou IY, Enchelmeyer B, Reed DJ (2013). The Value of Wetlands in Protecting Southeast Louisiana from Hurricane Storm Surges. PLOS ONE 8(3): e58715. https://doi.org/10.1371/journal.pone.0058715

Barbier, E. (2013). Valuing ecosystem services for coastal wetland protection and restoration: Progress and challenges . Resources, 2, 213-230.

Barbier, E. B. (1994). Valuing environmental functions: tropical wetlands. *Land Economics, 70*(2), 155–173.

Barbier, E.B., 1997, Ecological Economics, Uncertainty and Implications for Policy Setting Priorities for Biodiversity Conservation. *Investing in Biological Diversity: The Cairns Conference*, OECD, Paris, 1997, pp. 115-140.

Bea, K. 2005. Federal Stafford Act Disaster Assistance: Presidential Declarations, Eligible Activities and Funding. CRS Report for Congress. Congressional Research Service. The Library of Congress. RL 33053. Retrieved December 15, 2005, from https://biotech.law.lsu.edu/blaw/crs/RL33053.pdf

Bergstrom, J., Stoll, J., Titre, J., & Wright, V. (1990). Economic value of wetlands-based recreation. *Ecological Economics, 2*(2)

Boesch, D. F., Josselyn, M. N., Mehta, A. J., Morris, J. T., Nuttle, W. K., Simenstad, C. A., et al. (1994). Scientific assessment of coastal wetland loss, restoration and management in louisiana. Journal of Coastal Research, (20), 1-103.

Brody, S. D., Gunn, J., Peacock, W., & Highfield, W. E. (2011). Examining the Influence of Development Patterns on Flood Damages along the Gulf of Mexico. Journal of Planning Education and Research, 31(4), 438–448. https://doi.org/10.1177/0739456X11419515

Bryan, B. A., & Kandulu, J. M. (2009) Cost-effective alternatives for mitigating Cryptosporidium risk in drinking water and enhancing ecosystem services, Water Resources Research, 45, p. W08437.

Coastal wetlands initiative: Gulf of mexico review (2015). No. EPA-843-R-10-005D)United States Environmental Protection Agency.

Corps of Engineers, US Army Engineer District, New Orleans, Interim Survey Report, Morgan City, Louisiana and Vicinity, serial no. 63, US Army Engineer District, New Orleans, LA (November 1963).

Costanza, R. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*, 253.

Costanza, R., Perez-Maqueo, O., Martinez M. L., Sutton, P., Anderson, S. J., and Mulder, K., (2008). The Value of Coastal Wetlands for Hurricane Protection. *Ambio, 37*(4), 241–248.

Dahl, T.E. 1990. Wetland Losses in the United States 1780s to 1980s U.S. Department of the Interior, Fish and Wildlife Service, Washington. D.C. 13pp.

Dahl, T.E. and C.E. Johnson. 1991. Status and Trends of Wetlands in the Conterminous United States, Mid-1970's to Mid-1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 28 pages.

Davlasheridze, M, Fisher-Vanden, K and Klaiber, HA. (2017). The effects of adaptation measures on hurricane induced property losses: Which FEMA investments have the highest returns? Journal of Environmental Economics and Management, 81, 93-114.

Davlasheridze, M. & Miao, Q. (2019). Does Governmental Assistance Affect Private Decisions to Insure? An Empirical Analysis of Flood Insurance Purchases. Land Economics 95(1), 124-145. University of Wisconsin Press. Retrieved April 8, 2019, from Project MUSE database.

Engle, V. (2011). Estimating the provision of ecosystem services by gulf of mexico coastal wetlands. Wetlands, 31, 179-193.

Environmental Protection Agency. Section 404 of the clean water act: How wetlands are defined and identified. Retrieved March 25, 2018, from https://www.epa.gov/cwa-404/section-404-clean-water-act-how-wetlands-are-defined-and-identified

Farber, S. (1987). The value of coastal wetlands for protection of property against hurricane wind damage. Journal of Environmental Economics and Management, 14(2), 143-151.

FEMA. (2018). *Public assistance program and policy guide* No. 104-009-2

Gaddis, E. B., Miles, B., Morse, S., and Lewis, D. (2007). Full-cost accounting of coastal disasters in the United States: Implications for planning and preparedness. *Ecological Economics, 63*(2007), 307–318.

Garret A., T., & Sobel S., R. (2003). The political economy of FEMA disaster payments. *Economic Inquiry, 41*(3), 496.

Hammer, D.A., 1989, Constructed wetlands for waste water treatment: Chelsea, Mich., Lewis Publishers, Inc., 831 p.

Highfield, W., Brody, S., & Shepard, C. (2018). The effects of estuarine wetlands on flood losses associated with storm surge. Ocean and Coastal Management, 157, 50-55.

Kousky, C. (2010). Using natural capital to reduce disaster risk. Journal of Natural Resources Policy Research, 2(4), 343-356.

Kousky, C., & Shabman, L. (2017). Federal funding for flood risk reduction in the US: Pre- or post- disaster? Water Economics and Policy, 3(1)

Lindsay, B. R. (2014). FEMA's Disaster Relief Fund: Overview and Selected Issues. Washington, DC: Congressional Research Service. Retrieved December 15, 2014, from https://fas.org/sgp/crs/homesec/R43537.pdf.

Lindsay, B. R., & McCarthy, F. X. (2012). Stafford Act Declarations, 1953-2011: Trends and Analyses, and Implications for Congress (Vol. 31). Washington: Congressional Research Service.

Maltby, Edward (1986). *Waterlogged Wealth: Why Waster the World's Wet Places?* London: Earthscan Publications.

McCarthy, F. X. (2011). FEMA Disaster housing: from sheltering to permanent housing. DIANE Publishing.

Miller, S, R Muirwood and A Boissonnade (2008). An exploration exploration of trends in normalized weather-related catastrophe losses. In: *Climate Extremes and Society*, HF Diaz and RJ Murnane (eds.), pp.225-247. Cambridge: Cambridge University Press

Nahlik, A. M., & Fennessy, M. S. (2016). Carbon storage in US wetlands. *Nature Communications*

National Oceanic and Atmospheric Administration. Defining coastal counties. Retrieved March 13, 2019, from https://coast.noaa.gov/digitalcoast/training/defining-coastal-counties.html

National Wildlife Federation. (2014). Restoring the gulf of mexico for people and wildlife: Recommended Projects and priorities

Perry, CA (2000). Significant floods in the United States during the 20th century – USGS measures a century of floods. USGS Fact Sheet 024-00. Lawrence, KS: US Geological Survey.

Schuyet, K., & Brander, L. (2004). *The economic values of the world's wetlands*. Amsterdam: World Wild Life Fund.

Stromberg, D (2007). Natural disasters, economic development, and humanitarian aid. *Journal of Economic Perspectives*, 21(5), 199-222.

T.E., Dahl. (2011). *Status and trends of wetlands in the conterminous united states 2004 to 2009.* National Marine Fisheries Service and U.S. Department of the Interior, Fish and Wildlife Service.

US Department of Agriculture. (1995). *Wetland values and trends.* Natural Resources Conservation Service.

Woodward, R., & Wui, Y. (2001). The economic value of wetland services: A meta-analysis. Ecological Economics, 37(2), 257.

APPENDIX

Table A1: Correlation Table

	herb_acre	ln_income	rain_ano	ln_damage	unemp_rate	poverty_pct	vote_ind_pct	vote_dem_pct	floodplain
herb_acre									
ln_income	0.223**								
rain_ano	-0.008	-0.236**							
ln_damage	0.208**	0.239**	0.251**						
unemp_rate	-0.041	-0.503**	0.387**	0.118*					
poverty_pct	-0.136**	-0.608**	0.125*	-0.020	0.604**				
vote_ind_pct	0.144**	-0.246**	0.498**	0.148**	0.118*	-0.051			
vote_dem_pct	0.068	-0.115*	0.104*	0.234**	0.562**	0.591**	-0.233**		
floodplain	0.544**	0.117*	-0.068	0.095	-0.018	-0.021	0.085	0.081	
ln_pop	0.235**	0.519**	0.057	0.390**	-0.236**	-0.435**	-0.005	0.036	0.141**

Notes: Table reports Pearson's correlation coefficients for explanatory variables; ** p<0.01, * p<0.05