Identifying Socially Vulnerable Population to Storm Surge Flooding Based on Local Planning Needs: A Case Study of Lee County, Florida

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Abstract
Gulf of Mexico and Atlantic coastal communities share unique risks to location-based hazards from seasonal tropical cyclone events. These inevitable storms require local emergency management officials to prepare for and be capable to recover from the reality of powerful wind and water borne dangers. While most residents have the personal wherewithal to evacuate from an impending hurricane, there remain population segments who maintain an inability or a lesser ability to evacuate and or seek adequate shelter. Hazard susceptibility is exacerbated when considering the compounded effect of pre-existing socioeconomic characteristics. Beachfront communities are understandably the common focus of much hazard planning, but farther distance from the shore does not always equate to lesser vulnerability. This study utilizes experience from local government and emergency management officials, publically accessible data, and GIS technology to visualize sub-county spatial distribution of socially vulnerable populations to tropical cyclone borne storm surge through an additive calculation from simple spatial overlay. This study found that communities farther inland may have higher or equal vulnerability as coastal communities due to their socioeconomic status.

1. Introduction

Coastal American communities along the Gulf of Mexico and the southern Atlantic Ocean have a long history of preparing for and recovering from tropical cyclones. Historically, these seaside communities had little warning to prepare for an impending storm, and most residents simply hunkered down and waited for the storm to pass (Barnes, 2007 and Rowley et al., 2007). While these life threatening storms present an expected danger, population growth continues along at risk coastlines (Crowell et al., 2010, National Oceanic Atmospheric Administration, 2004 and Van Vuren et al., 2004). It seems counterintuitive to live in high risk locations, yet growing coastal populations guarantee that vulnerabilities will also continue to rise.

Greater knowledge of localized social vulnerability is paramount to matching resources with human need. In 2005, Hurricane Katrina ravaged the northern Gulf of Mexico. The American public watched news reports from New Orleans of residents who did not or could not evacuate and remained stranded on rooftops for days after the storm as sewage festering flood waters swirled below. This uncomfortable reality points to the much larger problem of sufficient resources for socially vulnerable populations (Cutter et al., 2006; Cutter and Emrich, 2006 and Clark et al., 1998). In the United States, municipalities are the first level of government to respond to a disaster and as such plan for potential evacuation. As well, most counties do not have resources to accommodate the population who, collectively, cannot provide transportation or adequate shelter before, during, and/or after a tropical cyclone (Cutter et al., 2006, Southwest Florida Regional Planning Council, 2010 and Cutter et al., 2000).

County emergency management officials put great time and effort into accounting for population needs when planning for disasters. It is understandable that significant local effort is put into conducting evacuation for mobile residents (Southwest Florida Regional Planning Council, 2010, Lee County Florida, 2009 and Bellomo and Crowell, 2010). However, segments of a community who are frequently marginalized due to economic and demographic considerations apart from a disaster scenario are more likely to receive less assistance during an evacuation. While plans exist for the accountability of all residents, scope and application of written plans can fall short.

Social vulnerability identifies and assigns a vulnerability index to preexisting socioeconomic conditions as a variable to ultimately determine vulnerability intensity (Cutter et al., 2003, De

Oliveira Mendes, 2009, Kleinosky et al., 2006, Odeh, 2002, Ozyurt and Ergin, 2010 and Schmidtlein et al., 2008). These indices were derived from spatial overlay of many layers of socioeconomic data. Localized social vulnerability to hurricane storm surge is a derivative of previous work completed by Cutter et al. (2003) and later on refined to sub-county level in 2013 (Cutter et al., 2013). They developed a metric, the Social Vulnerability Index (SoVI), for determining social vulnerabilities to natural disasters nationwide using county level jurisdictional boundaries as numeration units. They illustrate the SoVI metric at the county level utilizing US census aggregate data. Following their path, this research utilized census data as the identifier for socioeconomic characteristics though the difference here is considerations on local needs identified by county authorities. This approach takes a step closer to the ground level where local officials need data with greater detail.

The objective for this research is to understand the spatial distribution at the sub-county level of potential social vulnerability affected by storm surge in the Lee County, FL using publically accessibly data based on needs from local government and emergency management officials. This research adapted a bottom-up approach, different from the top-down approach commonly used in many academic research, to emphasize the needs of local government and emergency management officials who are the first ones to assess the seriousness of problem at hand, and have to make timely decisions on distribution of limited resources. The parameters used to construct the social vulnerability came from authors' working experience with local government and emergency management officials in a coastal community in Florida, US. This research showed how population disconnected from the immediacy of coastal landscape compared to coastal neighborhoods in terms of hazard information consumption and evacuation ability when considering existing personal resources. In this study, social vulnerability was derived from the identification and quantification of multiple socioeconomic conditions that contribute to the potential to have a lesser ability to fully consume hazard preparation information and evacuate to distant locations before and after a storm. Natural hazard impact and its possible human affect were accomplished through a GIS overlay of storm surge potential and the identified socioeconomic variables. Ultimately, these findings are intended to be applied in an operational setting for local emergency management officials as additional assessment tools and empirical evidence for local emergency planning documents. Pre-disaster planning is required for each county in the United States in order to qualify for FEMA (Federal Emergency Management Agency) financial assistance in the event of a disaster. In the hours prior to an impending hurricane and after any number of other hazards have occurred, greater detail of the local landscape is necessary to better allocate life saving resources to the most vulnerable population. This research provided a localized method to derive data for geographically narrow populations.

2. Study Area and Data Source

Lee County, Florida is a coastal community located in southwest Florida along the Gulf of Mexico (as shown in figure 1). Lee County is bisected near its northern border by the Caloosahatchee River and contains many barrier islands just off its western coast where the river empties. Access to the larger barrier island communities is by car over limited bridge locations. US Census Bureau estimated for Lee County has a 2010 population of 618,754 (United States Census Bureau, 2010).

There is currently limited sub-county social vulnerability research considering local needs conducted for Lee County, Florida. Lee County Emergency Operations Center (LEOC) maintains a mitigation plan for transit of special needs population. The Lee County Emergency Transportation Operations Plan (ETOP) section of the Comprehensive Emergency Management Plan (CEMP) provides mitigation for residents who are physically incapable of seeking shelter or evacuation transportation in the event of an impending storm (Lee County Florida, 2009). However, the ETOP is largely dependent upon pre-registration of these special needs population. While a contact method may be an effective form of service for many residents of the county to seek assistance, linguistically isolated populations are at an immediate loss and impoverished residents may lack communication resources to remain informed and could be at a disadvantage to notify emergency services of their need. Nepal et al., (2009) emphasized that language barriers are a common obstacle for immigrants to gain local knowledge about disaster preparedness and seek assistance or resources. In addition, undocumented migrants in southern Florida are a fast growing demographic who, not only may have limited language competency, but may also have an apprehension towards contacting emergency services for fear of deportation (Nepal et al., 2010).

The ETOP identifies neighborhoods in the county with higher concentrations of low and low-middle income residents (Lee County Florida, 2009). Through local mass transit, though dependent upon

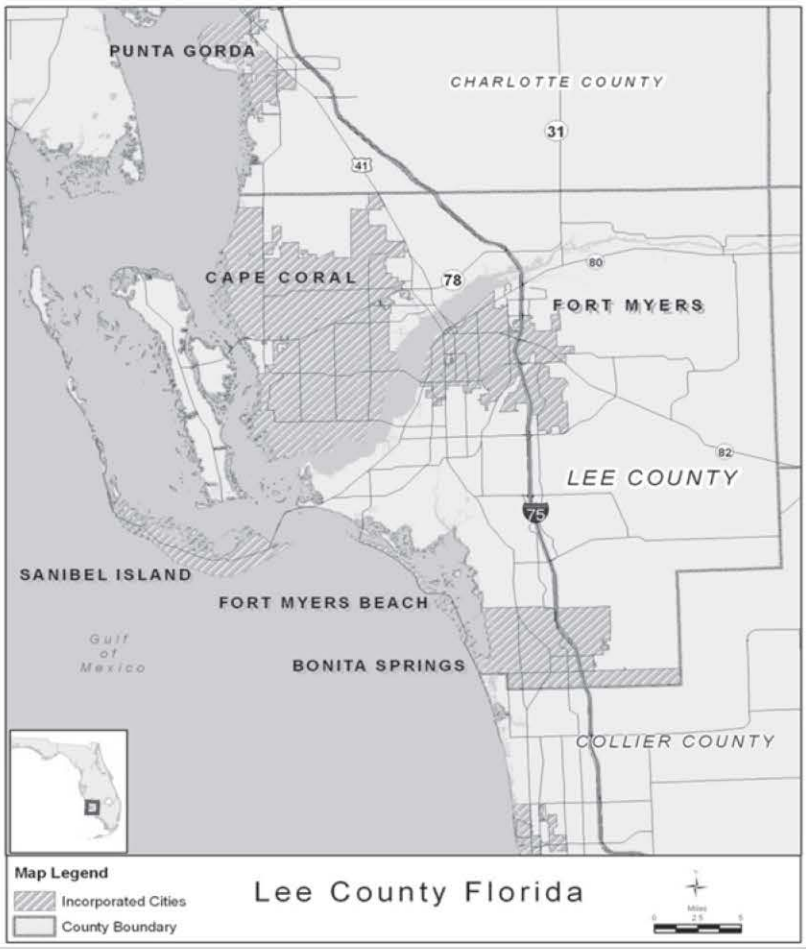

Figure 1. Study area: Lee County, Florida, USA

available staff and resource funding, this plan provides transportation for residents at bus stops with high ridership. This method does not account for actual residential locations. This is an important procedure to maintain during and after a storm event, but behavioral analyses suggested that many residents will wait until the last minute to make an evacuation decision and/or will seek shelter in a primary residence (Southwest Florida Regional Planning Council, 2010). The Lee County ETOP makes effort to deliver evacuation and recovery services to all residents in need, but considering limited disaster preparedness knowledge, language barriers, lack of personal resources to evacuate, and the potential stubborn human behavior; the need for additional social vulnerability awareness is desperately needed for local emergency management officials.

It is imperative that the storm surge model integrate vital pieces of spatial data which are specific to that modeling process. The data used for this study consists of: census data from US Bureau of Census, Light Detection and Ranging (LiDAR) derived digital elevation model (DEM), inland waterways, and storm surge extent.

3. Current Socioeconomic Profile

This research integrated three census variables using additive calculation through a GIS overlay to deliver a numeric value representing the intensity of potential risk to storm surge flooding, a concept similar to Social Vulnerability Index (SoVI) (Cutter et al., 2003, De Oliveira Mendes, 2009 and Schmidtlein et al., 2008). Variables were identified and extracted into a functional GIS layer:

1. Population who is under the national poverty line.
2. Population who does not have vehicular means for evacuating.
3. Population who have linguistic barriers.

Census variables were reclassified by dividing the raw variable number by the total population for each of the numeration units. In other words, census variables were normalized by population.

This percentage of the population was used as an intensity value rather than a true indication of the amount of humans potentially affected by a storm scenario. All populations over five years of age were included in this research. Population breaks were not used here. Each age group above five years of age were included equally. This research was interested in the largest amount of potentially impacted population that the census data provides. Potential impacted population is not segregated on age or sex lines. These three census variables were then added together in a spatial overlay operation (shown in equation 1) across the entire population within each numeration unit in Lee County to return a numeric value which represents the pre-existing circumstances that defines the potential for human vulnerability. This value does not represent an amount of population, but rather a compounded intensity value for human vulnerability potential from the identified socioeconomic characteristics.

$$CSEP = PL\% + NV\% + LB\%$$

Equation 1

Where CSEP is the current socioeconomic profile, PL% is the normalized population under national poverty line, NV% is the normalized population with no vehicle, and LB% is the normalized population with linguistic barriers.

Figure 2 provides a map for pre-storm spatial distribution of identified socioeconomic characteristics. Data in figure 2 were grouped using a quintile classification with 13 classes. The minimum value is .01 and the maximum value is .73. This map is best understood as a low to high range where green and associated colors are for lower values (lower social vulnerabilities) and red and associated colors are for higher values (higher social vulnerabilities). As seen in figure 2, pre-existing socioeconomic conditions are not great concerns for the near-shore island communities, but rather inland locations exhibit significant differences from locations closer to the coast. In particular is a compacted location south of the river and between State Highway 41 and Interstate Highway 75. Other higher values are in disconnected locations in south and east Lee County. Upland locations, where flood waters were not estimated, were areas considered without storm surge inundation and thus were treated as dry with no data and receive a null value. Though these locations were not included in the calculations and not in this research, real hazard potential persisted. Locations inland from this research remained highly vulnerable to wind hazards from hurricanes.

4. Proposed Social Vulnerability Affected by Storm Surge (SVSS)

The storm surge data was reclassified by using each category of storm to determine an intensity rating. This data was organized by category of storm into six individual raster layers. These six layers represent each of the storm categories: tropical storm and categories 1, 2, 3, 4, and 5. This intensity rating is a cumulative percentage where tropical storm receives the lowest intensity rating due to its lower destructive nature and a category 5 storm will receive the highest rating due to its large magnitude of destructive capability. Quantifying each category was achieved by dividing the number of category storms (6) by 100 which returns an even numeric distribution with increasing values for each of the six categories, as shown in table 1. This method did not reach absolute 100%, but the remaining value (.4%) was negligible, considering these percentages were used to represent intensity of a storm for a given location rather than parts of a whole.

Census tract data was converted into raster format from vector format. Raster format was used here for the calculation to operate within the spatial context as the layers overlay one another rather than a tabular calculation (Bolstad, 2008, DeMers, 2002 and Longley et al., 2005). Figure 3 displays the estimated inland extent for each of the six tropical cyclone scenarios within Lee County. An overlay additive calculation (shown in equation 2) was conducted in six iterations where each category of storm surge intensity rating was summed to the current socioeconomic profile.

$$SVSS = CSEP + SSR$$

Equation 2

Where SVSS is the proposed social vulnerability affected storm surge, SSR is the reclassified storm surge rating.

Outputs from all six layers were presented in cartographic layout (figures 4 - 9) to display the location and severity of residential social vulnerability for a given storm. Standardized symbology was used to visualize intensity comparison. Low intensity is depicted using green and, with increasing vulnerability, the color ramp gradually changes to red for the highest intensity. Given that the data comparison is between storm categories within the same county extent, results are best displayed as a low to high graduated color ramp rather than focusing on numeric values.

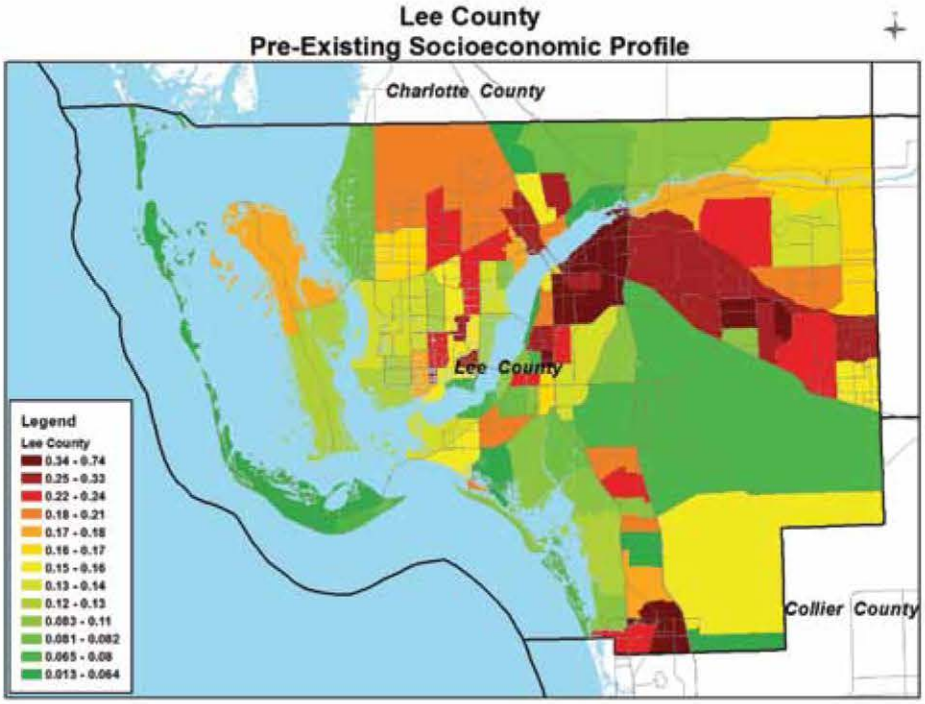

Figure 2: Lee County, FL pre-storm socioeconomic profile

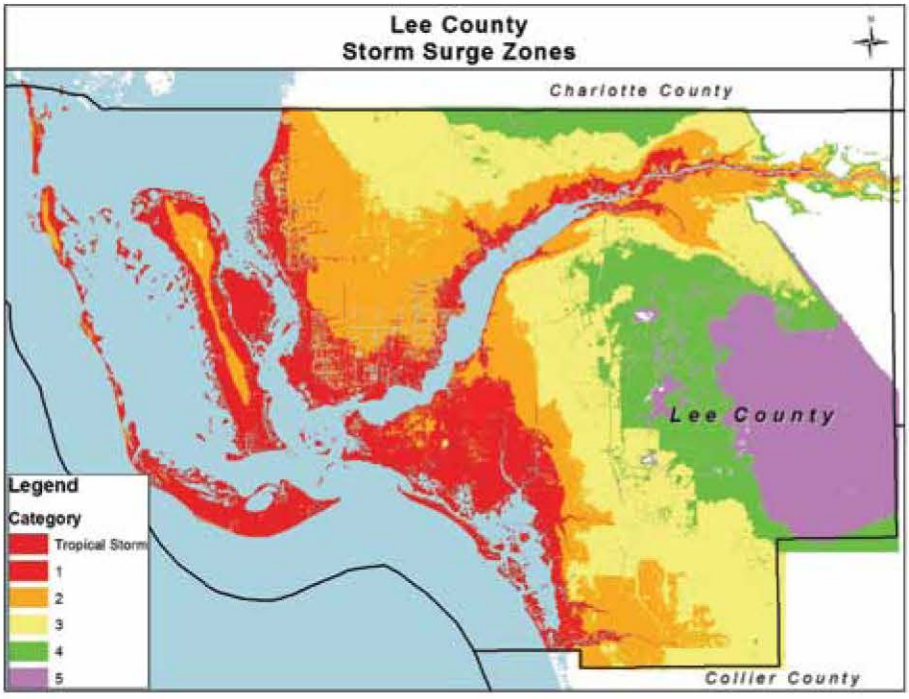

Figure 3: Lee County, FL storm surge zones (Source: SWFRPC).

Table 1: Tropical cyclone reclassification

Type	Tropical	Category 1	Category 2	Category 3	Category 4	Category 5
Rating	.166	.332	.498	.664	.83	.996

Figure 4: Tropical storm social vulnerability

Figure 5: Category 1 storm social vulnerability

Figure 6: Category 2 storm social vulnerability

Figure 7: Category 3 storm social vulnerability

Figure 8: Category 4 storm social vulnerability

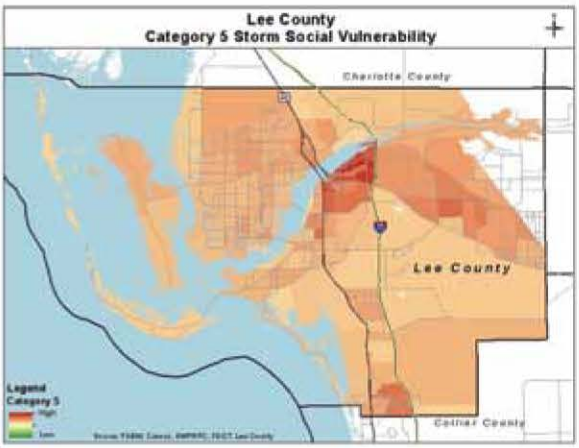

Figure 9: Category 5 storm social vulnerability

Figures 4 through 9 excluded census data beyond the storm surge extent. The overlay calculation was only performed on those locations where the particular storm surge was estimated to cover land. For example, tropical storm (figure 4) and category 1 (figure 5), only affect those areas closest to open water. This would mainly be locations with the lowest elevation. In figure 4 the majority of Sanibel Island, Fort Myers Beach, western and southern Cape Coral, and the mainland edges just across the bay from Fort Myers Beach are covered by estimated storm surge water. Figure 3 displays

inundation extent for each category of tropical cyclone. Tropical storm and category 1 storm are depicted as dark red and a slightly lighter red, respectively. The social vulnerability for tropical storm and category 1 is not clear due to the slight inland extent of storm surge potential. Not until category 2 storm do we begin to have a better visualization for comparative analysis.

Category 2 (figure 6) is the first inland extent of potential storm surge flood water which intersects locations identified exhibiting higher pre-storm vulnerability potential. While only relatively small portions of the county population intersect the estimated storm surge extent, the locations of higher social vulnerability to a category 2 storm begin to emerge just south of the river and in the extreme southern portion of the county. It is evident that the barrier island communities in western Lee County already have a lower vulnerability intensity to storm surge when compared to measured locations inland.

Categories 3 (figure 7) and 4 (figure 8) further illustrate locations of concentrated high social vulnerability. Again, these locations are just south of the river and in south central Lee County. The City of Cape Coral is a location with relatively moderate vulnerability intensity whereas the barrier island communities continue to be the lowest concentrations of socially vulnerable residents.

Figure 9 displays the sum calculation of category 5 storm surge inundation and the pre-existing population characteristics. This storm category covers the majority of the county and equally adds the category 5 intensity value (.96) to the entire inundated surface. This means that barrier island locations as well as inland areas all receive the same storm intensity weight during the overlay calculation. This is the worst case scenario storm surge estimate for Lee County. Only in figure 9 do we find a spatial distribution where the full extent of the potential worst case storm surge is calculated with all intersecting pre-storm conditions. Figure 9 greatly resembles the pre-storm census data chosen to investigate for this research. A category 5 storm is dangerous for the barrier island population, but we should not overlook the differences in socioeconomic characteristics. Vulnerability within Lee County is not as simple as looking for locations closest to the coast. Proximity to the threat of a disaster is not always the only location where special attention should be focused.

5. Effect of Storm Surge Extent

Tropical cyclone estimation is categorized into six storms of increasing intensity. Lower ranked storms extend only slightly from the coast whereas each consecutive storm of increasing intensity extends a greater distance inland from the coast. As the elevation gradient increases from the coast more inland, the estimate for potential storm surge inundation decreases. This research utilized census variables for the entire county, but the storm surge extent did not cover the entire county. The effect of these different spatial extents is apparent as shown by various amount of unaffected area (areas in white color) in figures 4 through 9. There were unprocessed county census data outside of the overlay calculation between the storm surge intensity and census dataset. Data outside the overlay was considered uncalculated data. Only census data beyond the extent of potential storm surge inundation was uncalculated, there was no storm surge data that is not included in this overlay.

In contrast to figures 4 through 9, figure 10 displays both the calculated (intersection) data and the non-calculated (outlier) census data which is beyond the extent of the storm surge data for tropical storm category. Upriver tropical storm extent barely brushes the shore without extending inland more than a few feet. The area just south of the river and between State Highway 41 and Interstate 75 is a compacted location with high pre-storm susceptibility potential. Tropical storm surge does not affect this area, but census data is available for this area. As one can see from figure 10, this area exhibits higher vulnerability than Sanibel Island. Nearly the entire Sanibel Island was estimated to be affected by tropical storm water. Thus, Sanibel Island was included in the calculation in figure 4. On the other hand, the area just south of the river, between state highway 41 and interstate 75, does not. Comparing figure 4 and figure 10, the area farther away from open water, which is not included in the tropical storm surge overlay calculation, exhibits a higher vulnerability, based upon its pre-storm socioeconomic profile, than does the entirety of Sanibel Island which was included in the tropical storm surge overlay calculation. The location upriver is adjacent to the river and susceptible to river affect, but the elevation gradient here is slightly greater than that of Sanibel Island and the distance from open water past barrier islands and through a winding river diminishes the potential for surge inundation.

Figure 11 provides another example also using outlier census data and the intersecting data calculation, but this time viewing category 1 storm data. The same location mentioned above remains largely outside of the storm surge inundation, yet continues to have higher pre-storm susceptibility values than the barrier island and near shore communities who are now affected by category 1 storm inundation. Additionally, farther east, past

Figure 10. Tropical storm calculated vulnerability and data beyond storm surge extent

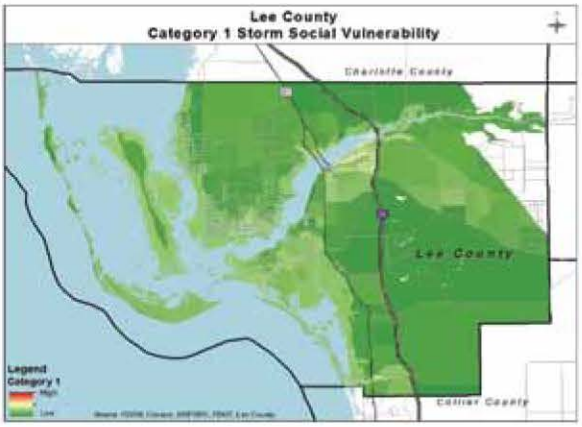

Figure 11: Category 1 storm surge extent and non-calculated census data

Interstate 75, there are locations which are even farther from the river and truly inland which also maintain greater social vulnerability intensity than that of the barrier island and near shore communities.

While these findings are important to focus attention and resources, proximity to open water should not be ignored. Barrier islands are vulnerable to storm surge on a greater scale based on adjacency to open water. The dangers of living on a barrier island are no secret when considering an impending storm. Flood waters are expectedly higher closer to the shore and the need to evacuate those residents first is required in local emergency management plans. However, this research is not focused on the dangers of living on a barrier island. These barrier island communities are potentially dangerous due to location and require special consideration for egress. This research is not blinded to the severity a storm unleashes on barrier islands and near shore communities; rather this research understands the geographic reality of coastal living. This research posits that barrier island and near shore communities have a greater physical danger to storm surge, but those residents also maintain a greater ability to utilize personal resources for evacuation and to seek adequate shelter. As evidenced in the pre-storm socioeconomic profile (figure 2), barrier island and near shore communities have relatively greater household income and few linguistic barriers. It is the lower income communities with less access to personal vehicles and limited by English language aptitude who are more susceptible to the dangers of storm surge flooding due to their lack of personal resources.

6. Conclusion and Future Research

This research adapted a bottom-up approach and put emphases on needs from local governments and emergency management officials, based on personal working experience. This research utilized simple overlay operations and publically accessible data to better understand sub-county social vulnerabilities to storm surge inundation. The output images depict a range of intensity for socially vulnerable locations to storm surge for each category of tropical cyclone. This study was based upon sensitive populations (under poverty line, no vehicle, linguistic barriers) who may be unaccounted or less than considered for before, during, and after a storm event. There is no variation within each storm category to express the flood differences across the landscape and the impact on the underlying residential population. However, as the results show, against common perception that high vulnerability for areas closer to coasts, specific inland populations do have higher vulnerability potential when viewing just census variables and without calculating a storm's impact than some near shore locations do with the same census variables but including a storm impact. This highlights a potential overlooked population that may require unique resource planning for a disaster event.

In addition to these final maps showing residents of high risks to storm surge flooding in the study area, the methodology developed in this study can be useful to other counties facing similar or different disasters. This study identified residents who have higher risks to storm surge flooding, but overlooked by nation-side or state-wide dataset or indices. These residents were identified through use of census variables and storm intensities, based on needs observed at the county or local authority level. The result is not to replace existing dataset or planning, but to supplement with a different viewpoint on directing local resources when emergencies happen. Data used in this study is publically accessible data. This study can be easily

transferred to other study areas with identified socioeconomic conditions and disaster extent.

Future research should remain within the county level using census tract or block group units, but a more regional extent may be of greater value. While first responders and mitigation plans are responsibilities of a county jurisdiction, hazards do not stop at the county boundary. Populations reside near and evacuate across political lines and communication between emergency management officials from neighboring communities should be aware of potentially vulnerable residents near a shared boarder. Incorporating local level numeration units across multiple counties within one research endeavor will provide a fine grain output which supply planning officials a decision making tool with greater precision.

Future research should focus on highlighting socioeconomic disparities within local communities. These unfortunate realities persist as glaring blemishes contributing to the inability for human safety during a natural disaster (Cutter et al., 2003). The immediate desired result of this sort of study is to better accommodate residents who require additional resources to evacuate and seek adequate shelter during a hurricane event. Nationwide scale cannot account for the high detail of unique local community characteristics that the inner county extent is capable. The scale of this project should remain local with the intent that local scale is best to enact meaningful change for all residents. Communities are better equipped to facilitate the needs of a marginalized population, understand the various personalities and relationships involved, and maintain a more personal atmosphere which often cultivates better communication.

Accepted research is validated through the application of scientific methods, though in this case personal safety is an immeasurable requirement all biotic life shares. Hopefully, this research can begin to assist populations on the fringes of society to provide safety mechanisms without the prerequisite of personal income to determine amount of safety.

References

Barnes, J., 2007, Florida's Hurricane History. 2nd ed.; University of North Carolina Press: Chapel Hill, North Carolina, United States.

Bellomo, D. and Crowell, M., 2010, FEMA's Coastal Population Study: Comments on Data Accuracy, Current Initiatives, and Future Risk. *Journal of Coastal Research*, 26(2), 199-200.

Bolstad, P., 2008, GIS Fundamentals: A First Text on Geographic Information Systems, 3rd ed. White Bear Lake, MN, USA: Eider Press.

Clark, G., Moser, S., Ratick, S., Dow, K., Meyer, W., Emnai, S., Jin, W., Kaperson, J., Kaperson, R. and Schwarz, H., 1998, Assessing the Vulnerability of Coastal Communities to Extreme Storms: The case of Revere, MA, USA. *Mitigation and Adaptations Strategies for Global Change*, 3, 59-82.

Crowell, M., Coulton, K., Johnson, C., Westcott, J., Bellomo, D., Edelman, S. and Hirsh, E., 2010, An Estimate of the U.S. Population Living in 100 Year Coastal Flood Hazard Areas. *Journal of Coastal Research*, 26 (2), 201-211.

Cutter, S., Boruff, B. and Shirley, W., 2003, Social Vulnerability to Environmental Hazards. *Social Science Quarterly,* 84 (2), 242-261.

Cutter, S. and Emrich, C., 2006, Moral Hazard, Social Catastrophe: The Changing Face of Vulnerability along the Hurricane Coasts. *The Annals of the American Academy of Political and Social Science*, 604, 102-112.

Cutter, S., Emrich, C. T., Mitchell, J. T., Boruff, B. J., Gall, G., Schmidtlein, M. C., Burton, C.G.; Melton, G. 2006. The long road home: Race, class, and recovery from Hurricane Katrina. Environment, 48(2), 10-20.

Cutter, S. L., Emrich, C. T. and Morath, D. P. 2013, Integrating Social Vulnerability into Federal Flood Risk Management Planning. *Journal of Flood Risk Management*, 6, 332-344.

Cutter, S., Mitchell, J. and Scott, M., 2000, Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina. *Annals of the Association of American Geographers*, 90(4), 713-737.

De Oliveira Mendes, J. 2009, Social Vulnerability Indexes as Planning Tools: Beyond the Preparedness Paradigm. *Journal of Risk Research*, 12(1), 43-58.

DeMers, M. N., 2002, GIS Modeling in Raster. New York, NY: John Wiley and Sons Ltd.

Kleinosky, L., Yarnal, B. and Fisher, A., 2006, Vulnerability of Hampton Roads, Virginia to Storm Surge Flooding and Sea Level Rise. *Natural Hazards*, 40(1), 43-70.

Lee County Florida, 2009, Comprehensive Emergency Management Plan: Emergency Transportation Operations Plan; Lee County, Florida: Fort Myers, Florida, United States.

Longley, P. A., Goodchild, M. F., Maguire, D. J., and Rhind. D. W., 2005, Geographic Information Systems and Sciences, 2nd Ed. West Sussex, U.K. John Wiley and Sons Ltd.

National Oceanic Atmospheric Administration (NOAA), 2004, Population Trends along the Coastal United States: 1980-2008. United States Department of Commerce: Washington D.C., United States.

Nepal, V., Scott, D., Banerjee, D. and Perry, M., 2009, Understanding Disaster Preparedness of Linguistically Isolated Population Groups: Chinese, Vietnamese, Somali and Spanish Speaking; Community Health Statistics, Office of Surveillance and Public Health Preparedness, Houston Department of Health and Human Services: Houston, TX, United States.

Nepal, V., Banerjee, D., Slentz, M., Perry, M. and Scott, D., 2010, Community-Based Participatory Research in Disaster Preparedness among Linguistically Isolated Populations: A Public Health Perspective. *Journal of Empirical Research on Human Research Ethics: An International Journal*, 5(4), 53-63.

Odeh, D. J., 2002, Natural Hazards Vulnerability Assessment for Statewide Mitigation Planning in Rhode Island. *Natural Hazards Review*, 3(4), 177-187.

Ozyurt, G. and Ergin, A., 2010, Improving Coastal Vulnerability Assessments to Sea-Level Rise: A New Indicator-Based Methodology for Decision Makers. *Journal of Coastal Research*, 26(2), 265-273.

Rowley, R., Kostelnick, J.C., Braaten, D., Li, X. and Meisel, J., 2007, Risk of Rising Sea Level to Population and Land Area. Eos, *Transaction American Geophysical Union*, 88(9), 105-116.

Schmidtlein, M., Deutsch, R. C., Piegorsch, W. W. and Cutter, S. L., 2008, Building Indices of Vulnerability: A Sensitivity Analysis of the Social Vulnerability Index. *Risk Analysis*, 28(4), 1099-1114.

Southwest Florida Regional Planning Council (SWFRPC), 2010, Southwest Regional Evacuation Study; Southwest Florida Regional Planning Council: Fort Myers, Florida, United States.

United States Census Bureau. 2010. State & County Quick Facts. Available from: http://quickfacts.census.gov/qfd/states/12/12071.html. [Accessed 13 August 2013].

Van Vuren, S., Kok, M. and Jorissen, R., 2004, Coastal Defense and Societal Activities in the Coastal Zone: Compatible or Conflicting Interests? *Journal of Coastal Research*, 20(2), 550-561.