Block Group Social Vulnerability to Storm Surge Flooding: Case Study of East Little Havana-Miami.

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Abstract
Coastal regions are vulnerable to natural hazards such as storm surge flooding. Increased population growth and wealth in coastal areas have led to swelling costs associated with flood-related damages, as evidence in Miami-Dade County, Florida across the decades. While the federal government and the states continue to put in early warning systems to provide resilience and adaptation strategies, lessons learned from Hurricane Katrina indicated that the social predisposition to hazards is more dynamic and rather negatively tend towards poor and minority neighborhoods. Thus, in order to obtain information about the dynamics of social vulnerability within Miami-Dade County so as to increase resilience and adaptation measures, this study used East Little Havana (ELH) as a case study site to assess social vulnerability to storm surge flooding in the county. The study used GIS, demographic and socioeconomic data to perform principal component analysis of the block-groups in ELH.

The results indicated that average household sizes, average income, and median age are the main determinants of social vulnerability within the neighborhood. A SoVI index developed from the scores of the components indicated that low vulnerability areas are along the Miami River, encompassing some parts of Downtown Miami. Very high and high vulnerability areas on the other hand include higher density neighborhoods, where residents tend to have larger family sizes, in addition to low income.

In all, the result of the study agreed with earlier studies, which cited income, family sizes, and age as some of the major determinants of social vulnerability in the US.

Introduction

Social vulnerability assessments have become essential aspects of recent studies, since they reveal societal predispositions for suffering harm when areas are affected by flood hazards (Garschagen and Sandholz, 2018). In the US, social vulnerability assessment gained more popularity in the aftermath of Hurricane Katrina, when the lack of resources due to social inequalities prevented over 250,000 people, mainly ethnic minorities, from fleeing New Orleans (Cutter, et al, 2006). Since then, social vulnerability mapping of coastal cities has been an integral part of studies searching to identify inequalities in the ways different parts of a community may react to a disaster (Reid, et al, 2009; Flanagan, et al, 2011; Van Zandt, et al, 2012). According to Cutter et al (2000), parameters for measuring social vulnerability are derived from activities and circumstances of everyday life or its transformations. Cutter et al (2003) developed the Social Vulnerability Index (SoVI) framework that can be used to assess geographic patterns of social vulnerability to environmental hazards. According to the study, some of the fundamental determinants of social vulnerability in the US include personal wealth, age, race, ethnicity, and occupation. The study indicated that social vulnerability has distinct spatial patterns and the factors that contribute to SoVI are often different for each geographic unit under consideration.

In a recent study, Pricope et al (2019) modelled the vulnerability of residential block-groups to coastal flooding in North Carolina (NC). The study combined social vulnerability parameters mainly socioeconomic status, age, gender, race, family structure, and total population, with flood hazard maps to assess the vulnerability of residential buildings to coastal flooding. The

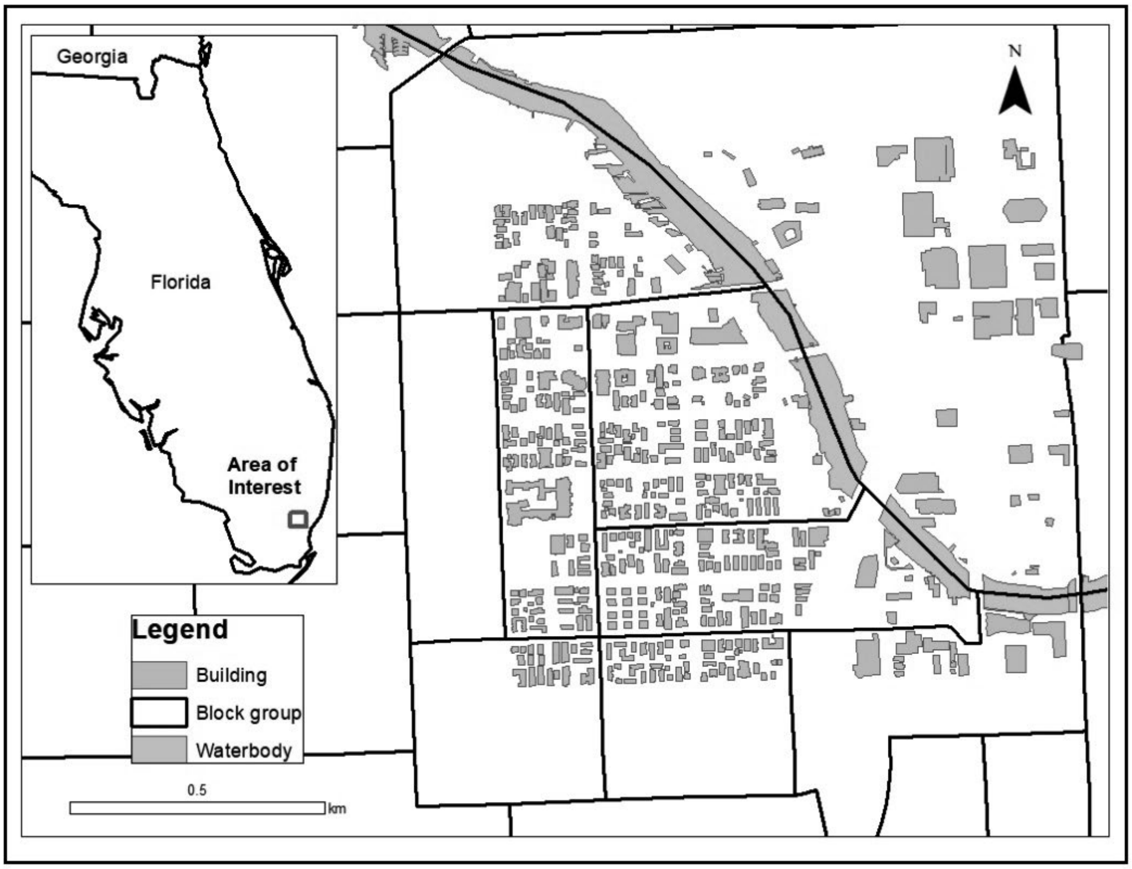

Figure 1. Location of East Little Havana

study found that 45.3% of structures within the 100-year floodplain were structurally exposed to potential damage from inundation. The findings supported the hypothesis of the study, that, neighborhoods close to coastal water are more vulnerable to coastal flood inundations. The research stressed that social vulnerability assessment is essential for the planning and adaptation of US coastal cities, especially in the wake of recent extreme storm surge flooding and hurricanes.

Miami-Dade County is one of the leading US economic hubs that has been earmarked to be highly susceptible to storm surge flooding (Gornitz, et al. 1994). The county has experienced some of its costliest hurricane related damages in recent past decades, and the costs are predicted to increase under projected climate change scenarios. Bjarnadottir, et al. (2011) developed the Coastal Community Social Vulnerability Index (CCSVI) to quantify the vulnerability of some areas within the county to climate change. The study provided useful information about the social vulnerability in the county. However, the continual influx of people and the fast-paced infrastructure development in the county only necessitates that a similar updated study be carried out to reflect current status. Moreover, the earlier study only assessed inter-community social vulnerability as opposed to intra-community which can reveal the social disparities within the same community. This study was therefore conducted to develop a storm surge social vulnerability map for Miami-Dade County with the East Little Havana (ELH) neighborhood as a case site.

Methodology and Materials

Study area

The area considered in this study is conformed by the block-groups encompassing East Little Havana (ELH) and a portion of Downtown Miami in Miami-Dade County. Bordering Downtown Miami to the east, Little Havana to the west, Allapattah to the north and Coral Way to the south, ELH is a rather poor neighborhood in a highly commercialized city. Deriving its name from the Cuban capital and largest city, Havana, ELH is home to many Cubans as well as immigrants from other Central and South American countries. ELH as well as Little

Havana are noted for their political, social, and cultural activities. The neighborhood is also characterized by street life, restaurants, music, smaller family-owned or independent businesses, and great warmth among its residents.

Dividing ELH and Downtown Miami is the Miami River, which has historically overflown its banks during higher category hurricanes and storm surge flooding (TNC, 2020). Floodwaters from Hurricanes Irma inundated some residential and commercial properties along this stretch of the river, disrupting business and causing infrastructural damages (FEMA, 2018). Recent tide measurements and other observations indicate that the frequency of 'King Tide', which is a phenomenon, caused by the specific alignments of the sun and moon, is on the rise and will likely increase the frequency of flooding in these coastal neighborhoods (Cardona, 2019). In addition, climate change is projected to increase the frequency and severity of floodwaters from storm surges (Woetzel et al., 2020), which has the potential to increase floodwaters reaching the river, and consequently increase the inundation extents of the river. This will have exacerbated impacts on homes and business around these areas. Moreover, with recent evidences of the rather higher consequences of coastal flooding on the poor and ethnic minorities, as was observed during Hurricane Katrina (Cutter et al, 2006), ELH is an ideal case site to study disparities in social vulnerability resulting from its predisposition to storm surge hazards in Miami-Dade County. A SoVI of this neighborhood is thus useful to city managers, county authorities, the state of Florida and the nation as a whole, who seeks to plan and prepare for imminent flood disasters knocking on the doors of coastal cities.

Data

The data sets used in this study were a subset of data collected as part of a broader study to assess the physical and social vulnerability of buildings to storm surge flooding in Miami-Dade County. The broader dataset included GIS shapefile of buildings, transportation infrastructure, parks and recreational areas, coastal and inland waterbodies, and other land use/ land cover (LULC) types. The data also included boundary shapefile of block-groups, artificial reefs and FIRMs zones. All of that data was obtained from the University of Miami library. In addition, a Synoptic Survey was carried out to gather ground truth information about the various datasets as well as new ones. On the other hand, all the social and demographic data was obtained from the U.S. Census Bureau website, Census Reporter. These latter sets of data were composed of tabulated information about populations, age, sex, ethnicity, race, income, and other socioeconomic status. Datasets relating to ELH were downloaded, a comma separated values (CSV) files and were joined together in a single worksheet using their GeoID as primary key. The variables considered for analysis are average household size, median income, median age, race-Hispanic and Latino, race-black, marital status, and population density.

Methodology

Social Vulnerability

Principal component analysis (PCA) was used in determining the social vulnerability index (SoVI) for the different block-groups within the East Little Havana neighborhood. PCA is a mathematical technique for transforming correlated variables into uncorrelated variables known as principal components (Costello and Osborne, 2005). It is a dimension-reduction tool that can be used to reduce a larger set of variables to a smaller set that still comprehends most of the information in the larger set (Costello and Osborne, 2005). Components are determined based on the proportion of variance in the population explained by the larger dataset (Pricope, et al, 2019). In using PCA, it is assumed that the score and loading vectors belonging to the largest eigenvalues contain the most useful information relating to the specific problem, and that the remaining ones mainly comprise noise.

This study used the Stata software for the PCA. To reduce the tendency of any variable loading too highly on a single component, a varimax rotation was used to simplify the structure of the underlying dimensions and produce more independence among the components (Mavhura, et al, 2017; Pricope, et al, 2019). The Kaiser criterion, with eigenvalues > 1, was then used for component extraction (Mavhura, et al, 2017). The arithmetic signs of the component were used to judge their respective influence on vulnerability with positive values being considered to be contributing to vulnerability while negative values were deemed to decrease vulnerability (Mavhura, et al, 2017).

Table 1. Components scores and SoVI index obtained from the Principal Components Analysis

Block-group	PC 1	PC 2	PC 3	SoVI
36011	-3.3215	-0.6958	-0.8195	-4.8367
36021	-2.0659	-0.2548	-1.0396	-3.3604
36024	-0.7240	0.6815	-0.9500	-0.9925
66021	1.9054	-1.8358	-0.8147	-0.7450
66024	-0.6889	0.3887	-0.3753	-0.6755
36025	-0.8983	0.6932	-0.1073	-0.3124
36023	-0.5703	0.8848	-0.1659	0.1486
66023	-0.7844	0.8621	1.5048	1.5825
36022	1.1607	1.0299	-0.2104	1.9802

After selecting the principal components based on their variances, a SoVI was developed by utilizing the component scores of each block group. The final SoVI scores were classified using the standard deviation from the mean method, which provided a relative measure of deviation from the mean of each block-group. This resulted in the classification of the values from 1 to 5, with 1 indicating a very low social vulnerability and 5 indicating a very high social vulnerability. The results were formatted in Microsoft Excel and then joined to their respective block-groups in a GIS environment for visualization.

Results and discussion

Component Scores

The correlation matrix showed that people with no schooling and people with only a college degree correlated highly with average household size (Pearson's r were 0.8 and 0.6 respectively). Population with college degree also fairly correlated with median income (Pearson's r=0.54). As such the no school and college variables were eliminated from the PCA. The seven remaining variables had Pearson's correlation coefficient of <0.5 and was used the further analysis. Assessment of the PCA identified 3 major components that explained a cumulative 68% of the variation in the data. Using the Kaiser Criterion and eigenvalue scree distribution, the percentage variance of the 3 components were extracted. Average household size was the first and largest component, and explained 29.67% of the variation in the data. The second component explained 19.98% of the variation and was associated with the median income within the block-groups. The third component explained 18.30% of the variation and was related to the median age. These major variables identified by this study agrees with the result of the social vulnerability assessment conducted by Bjarnadottir et al. (2011).

Both studies agree that socioeconomic status, and age are some of the main contributing factors of social vulnerability in the county. The results also agree with other social vulnerability studies conducted outside of the county, for example Pricope, et al. (2019) in North Carolina that identified household size, as a major determinant of social vulnerability within the continental US. The scores of each component was is shown in Table 1.

Social Vulnerability Index (SoVI)

The geographical distribution of the social vulnerability of ELH neighborhoods is shown in figure 3. Using the standard deviation from the mean method, the vulnerability of the block-groups includes very low, moderate, high and very high. Very low vulnerability areas are up the Miami River, entering the neighborhoods of Downtown Miami. This is a commercial area with high rise buildings and businesses. They also include federal and state buildings which are mostly used as offices. However, residents within this neighborhood are usually workers

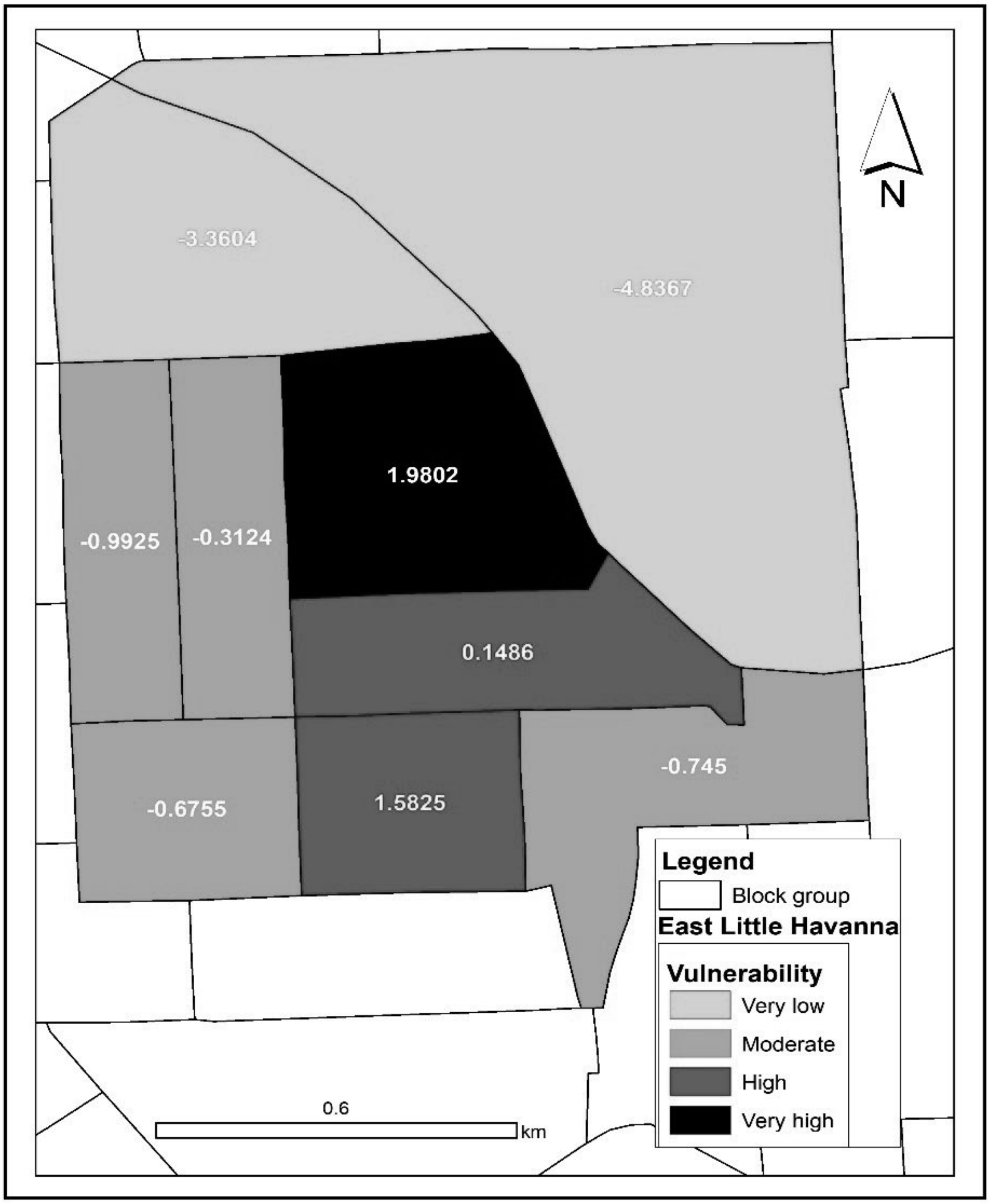

Figure 2. The geographical distribution of the social vulnerability of East Little Havana

who are middle to high income earners, as well as having smaller family sizes. The structural strength of the buildings in this area also reduces the vulnerability of these areas to a very low level as residents become least affected by flood inundations. Moderate vulnerability areas encompass a mixed residential and small business block-groups. Buildings within this area usually ranges from two – five stories high, which are moderately affected by flood inundations. Moderate vulnerability block-groups contains a mixture of residential and family owned businesses. Average income thus lies between low and medium, and residents may be gainfully employed. High and very high vulnerability areas are those that are of social vulnerability within the block-groups. Buildings within these block-groups are mostly one story high, with or without a habitable space above the ground floor. The neighborhoods also tend to have compact building arrangement and thus increase the people per unit area within the block-group. Residents within these areas are mostly low-income earner and tend to have greater family sizes.

Conclusion

This study assessed the social vulnerability of East Little Havana to storm surge flooding. The study used GIS data as well as demographic and socioeconomic data of the block-groups to perform principal component analysis in the Stata software. The result indicated that average household sizes, average income and median age are the main determinant of social vulnerability within the block-groups.

A SoVI index developed from the scores of the components indicated that low vulnerability areas are up the Miami River, encompassing some parts of Downtown Miami. Very high and high vulnerability areas on the other hand include higher density neighborhoods and residents tend to have larger family sizes in addition to being low income earners. In all, the result of the study agreed with earlier studies that assessed the social vulnerability of communities within the county and elsewhere in the US, which cited income, family sizes, and age as some the major determinants of social vulnerability in the US.

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