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Social vulnerability in Louisiana's upper industrial corridor: spatial distribution and linkages with cumulative pollution - a zip code level analysis

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SOCIAL VULNERABILITY IN LOUISIANA'S UPPER INDUSTRIAL CORRIDOR: SPATIAL DISTRIBUTION AND LINKAGES WITH CUMULATIVE POLLUTION – A ZIP CODE LEVEL ANALYSIS

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Abstract

Louisiana's industrial corridor, the stretch of the lower Mississippi River from New Orleans to Baton Rouge, is one of the areas with the highest concentration of petrochemical facilities and chemical plants in the United States, as well as one of the most heavily polluted. In particular, the present study examined the associations of social vulnerability and potential exposure to environmental pollution in the upper section of the industrial corridor, the Baton Rouge Metropolitan Statistical Area (MSA). The study was based on the methodology developed by Cutter et al. (2003) to construct an empirically derived index to measure social vulnerability to environmental hazards. The data were collected at the zip code level for the year 2000. First, the underlying components of social vulnerability in the area were identified, that is, the socioeconomic factors that may result in unequal access to resources and that might affect the ability of communities to respond to hazard events. Poverty, urbanization, elderly, affluence, female and children, and race and ethnicity, were the six most relevant components in explaining the social vulnerability of the area at the zip code level. Second, the spatial distribution of social vulnerability was determined, with the most vulnerable zip codes clustered in the northwest portion of the region. Finally, the nature of the relationships between social vulnerability and environmental exposure risks was studied using Toxic Release Inventory (TRI) data at the zip code level. Significant associations ($\alpha = 0.05$) were found between environmental pollution and the urbanization and elderly components of social vulnerability. Furthermore, no significant correlation was found between toxic emissions and the overall social vulnerability index scores at the zip code level for the Baton Rouge MSA.

Chapter 1
Introduction

The nine-parish area surrounding Baton Rouge forms the upper section of Louisiana's industrial corridor and is home to numerous petrochemical facilities and other regulated industrial plants emitting thousands of pounds of toxic substances to the air, water and land each year. Environmental justice studies have found that in many heavily industrialized communities, poor and minority residents are disproportionately represented in neighborhoods closest to noxious facilities. The question of how socioeconomic vulnerability and proximity and potential exposure to environmental pollution may be associated is important to discussions of distributions of environmental risks.

Cutter et al. (2003) developed a widely used empirical index to measure social vulnerability of residents at the county level throughout the United States. The social vulnerability index (SVI) is useful in identifying spatial relationships and temporal changes in key attributes of communities that make them more or less susceptible to external disturbances. The SVI also offers a systematic and theory-based approach to quantifying community vulnerability that is useful in examining how vulnerability levels may be associated with or influenced by proximity to environmental exposure risks. This study examines the nature of the associations between social vulnerability and environmental pollution in this heavily industrialized area of Louisiana. In this regard, the study makes an initial contribution to the environmental justice research from the theoretical framework of social vulnerability and the vulnerability-of-place literature.

The objectives of this study are:

1. To construct the SVI at the zip code level, a finer scale than originally used by Cutter et al. (2003), to identify key components characterizing social vulnerability in Louisiana's upper industrial corridor.

2. To determine the spatial distribution of social vulnerability index scores, in particular areas of lowest and highest vulnerability levels.

3. To explore and determine whether there are significant statistical associations between social vulnerability and environmental exposure risks among communities within the 83 zip codes of the upper industrial corridor of Louisiana.

This is an important initial step in identifying those communities that are most in need of socially based services (including health, welfare, housing, and education), which would enhance their ability to respond and recover from hazard events (1). The findings of the study may serve as benchmarks of social vulnerability and indicators of environmental pollution that can be used to identify changes in the nature and spatial distribution of social vulnerability and exposure conditions over time.

Chapter 2
Vulnerability

The term vulnerability, originally used in geography and hazards research, is now a central concept in various fields of study, including ecology, poverty and development, public health, sustainability, and climate change, among others (2). Vulnerability is conceptualized in many different ways depending on the field of study and orientation, and so there is an ongoing debate on its characterization in theory and in practice (3). However, in a broad sense, vulnerability is the degree to which a system is likely to experience harm from the risk posed by hazard events at a particular location (4). Risk is a "measure of the probability that a hazard event will occur and adversely affect a population" (4). A hazard is a potentially damaging physical event or human activity that "may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental degradation" (5).

Vulnerability research has traditionally focused on the biophysical processes and built environment factors, but in recent years social inequalities have been increasingly recognized. Social inequalities refer to the social conditions of interaction and development resulting in the stratification in the access to resources (6, 7). In fact, "there are no generalized opportunities and risks in nature, but instead there are sets of unequal access to opportunities and unequal exposures to risks which are consequences of the socioeconomic system" (7).

Social vulnerability can be defined as a measure of the sensitivity of a population to the effects of natural or human-induced hazards and its ability to respond and recover from the impact those hazards (1). Major factors influencing social vulnerability include the "lack of access to resources (including information, knowledge, and technology), limited access to political power and representation, social capital (including social networks and connections), beliefs and customs, frail and physically limited individuals, and type and density of infrastructure and lifelines" (6).

2.1 Hazards-of-Place Model of Vulnerability

To combine the two factors of vulnerability, namely biophysical and social, Cutter (1996) proposed the hazards-of-place model of vulnerability (Figure 2.1).

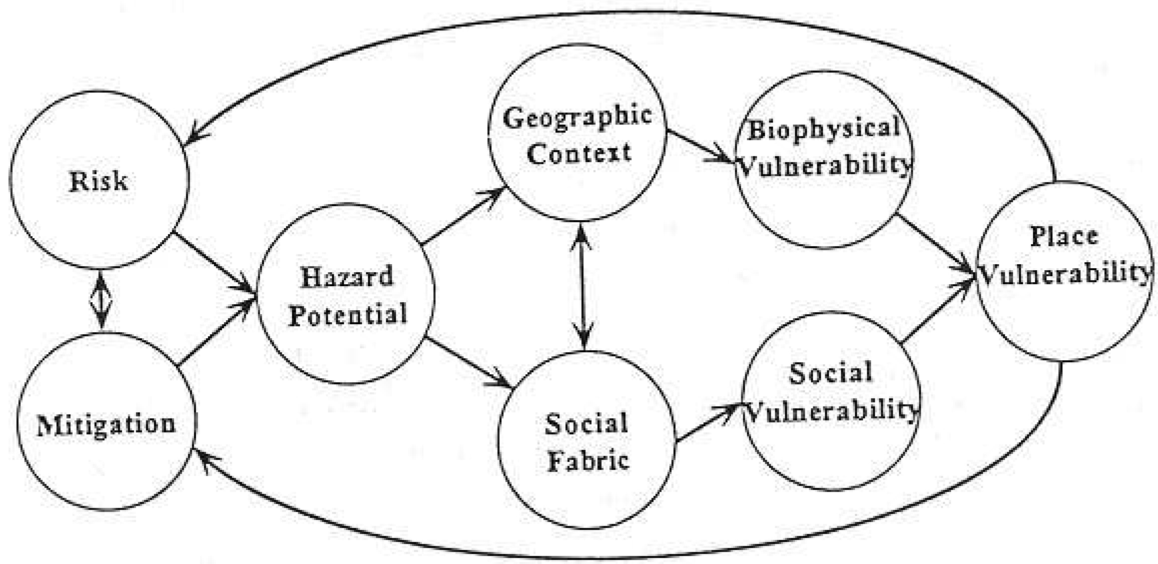

Figure 2.1: The hazards-of-place model of vulnerability* (8).

Risk interacts with mitigation (the efforts to lessen risks and the adverse impacts of hazards) to create an initial hazard potential. The hazard potential is moderated by the geographic context and the social fabric of the community. The geographic context, which includes the site, place characteristics, and the proximity and frequency of hazard events, combines with the hazard potential to form the biophysical vulnerability. Conversely, the social fabric includes the community experience with hazards, its organizational capacity, and its ability to recover and adapt to external and internal disturbances, all of which are mediated by the economic, demographic, and housing characteristics of the community. The hazard potential interacts with the social fabric to produce the social vulnerability (6, 9). The combination of social and biophysical vulnerabilities results in the overall place vulnerability, which in turn affects the initial conditions of risk-mitigation capabilities.

* Used with permission of the publisher. Copyright permission is given in Appendix A.

2.2 Measuring Vulnerability

Vulnerability is a dynamic interaction of diverse biophysical and social processes that shape local conditions. Thus, a multi-stressor context is an important factor in evaluating vulnerability. Measurements of vulnerability must reflect the material outcomes, social processes, and complex linkages within a system, many of which are not easy to identify. However, the translation of diverse stressors into a single metric of vulnerability is challenging and may reduce their impact and complexity (10). In particular, social vulnerability is difficult to quantify, which explains, for example, its absence in most after-disaster cost estimation reports (6). Nonetheless, in order to promote mitigation strategies at the local level, it is imperative to create methods for identifying and measuring the risks posed by multiple hazards, that when coupled with qualitative studies, can provide more complete insight into the underlying factors and perceptions of vulnerability (9, 10).

Measures of vulnerability must also incorporate spatial factors, those that account for the spatial distribution of vulnerability within a particular area, and temporal factors, those concerned with the temporal dimensions of risk, that is, "whether vulnerability is a transient phenomenon associated with exposure to particular risks, or is a chronic state" (10).

Another factor is the scale-dependent nature of vulnerability. It is a concern in the identification of the unit of analysis, in understanding the influence of cross-scalar dynamics in the vulnerability of place (as the significance of indicators can change with scale and degree of aggregation), and in the practicality of the study. In fact, some researchers argue that vulnerability assessments must select scales that are congruent with the geographic levels at which management occurs; in other words, the needs and interests of the stakeholders should drive the design and the scale of the project (3, 11).

These factors, along with issues of data quality and availability, difficulties in the methodology, and conceptual shortcomings within the vulnerability science, have limited the development of consistent measures of social vulnerability. However, important attempts have been made to measure vulnerability at the national level (specifically for hazard and disaster indicator studies), subnational spatial scales, and more detailed vulnerability metrics using subcounty enumera-

tion units within the United States (1). For example, Cutter et al. (2003) developed the social vulnerability index, a multivariable approach to "quantify variations in the relative levels of social vulnerability over time and across space"; initially this method was used to measure the social vulnerability of the United States at the county level, but it has been replicated to quantify vulnerability at various spatial scales, time periods, and geographic settings (12). This approach was applied in this study to examine patterns of social vulnerability in Louisiana's upper industrial corridor.

Chapter 3
Area of Study

The Baton Rouge Metropolitan Statistical Area (MSA), also known as Greater Baton Rouge, forms the upper section of Louisiana's industrial corridor. It is located in the southeastern portion of the state, encompassing nine parishes, namely, Ascension, East Baton Rouge, East Feliciana, Iberville, Livingston, Pointe Coupee, St. Helena, West Baton Rouge, and West Feliciana, as defined by the Office of Management and Budget as of December 2009 (13). It is anchored by the state's capital city, Baton Rouge, which is also the second largest city in Louisiana, and the home of Louisiana State University and Southern University. A map of the area can be seen in Figure 3.1.

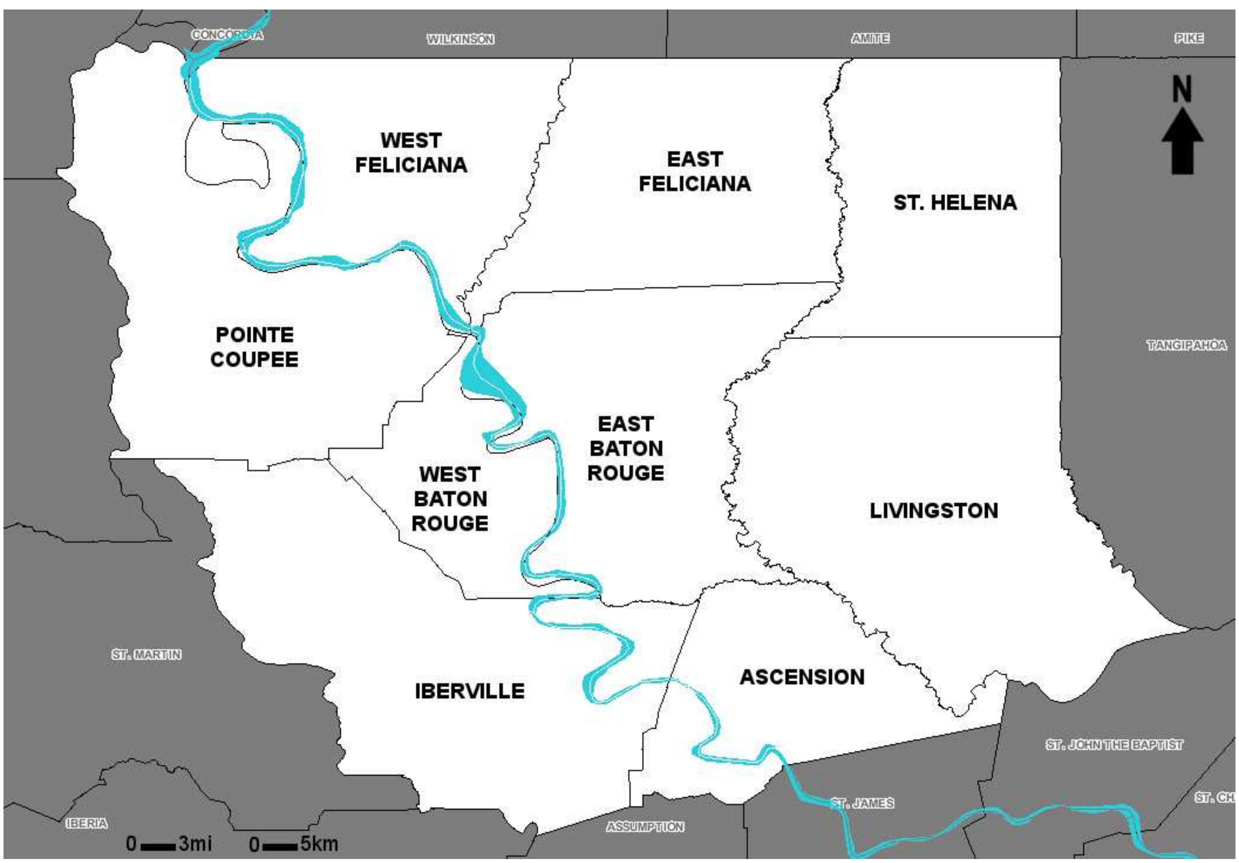

Figure 3.1: The Baton Rouge MSA and its constituting parishes.

In the last ten years, the population in the Baton Rouge MSA grew 33%, from approximately 600,000 people in 2000 to 800,000 in 2010. This sharp rise in population has likely strained community services and resources in the last decade, increasing the vulnerability of the area to hazard events. On the other hand, in the year 2000, Greater Baton Rouge was above the state of Louisiana in most indicators of economic well-being, but still below the national average (Table 3.1).

Table 3.1: General demographic characteristics of the Baton Rouge MSA (Source: U.S. Census).

Year 2000	Baton Rouge MSA	Louisiana	United States
Percent population change 2000 - 2010	33.1	1.4	9.7
Percent African American	31.9	32.5	12.3
Percent White	64.9	63.9	75.1
Median age	31.9	34.0	35.3
Percent population with bachelor's degree or higher	24.9	18.7	24.4
Percent population 16 years and over unemployed	3.8	4.3	3.7
Median household income (dollars)	38,438	32,566	41,994
Per capita income (dollars)	18,867	16,912	21,587
Percent population below poverty level	16.2	19.6	12.4
Median value of owner-occupied housing (dollars)	98,500	85,000	119,600

The Greater Baton Rouge area is also home to numerous petrochemical facilities and other regulated industrial plants. The rise of the petrochemical industry in the lower Mississippi River corridor started with the construction of Standard Oil's Baton Rouge refinery in 1908, and was accelerated in the 1960's due to the availability of crude oil, natural gas, water, salt, and sulfur, the primary raw materials for the production of petrochemicals. The area offered easy access to oil and gas, deepwater transportation capabilities, water for industrial process, and a mild climate (14, 15).

The high flow rate of the Mississippi River was also ideal for the discharge and dispersion of contaminants, which became a major consideration after the passage of the Water Quality Act in 1965. Louisiana's tax exemptions and regulatory leniency also contributed to the growth of the chemical industry. For example, since 1936, the state has offered an industrial-property tax exemption that, unlike other southern states, is granted without local approval (16).

Louisiana manufactures one quarter of the petrochemical production in the United States, including basic chemicals, plastics, and fertilizers; a large number of petrochemical facilities operating in the state are located in the Greater Baton Rouge region (17). The ExxonMobil refinery in Baton Rouge, for example, is second largest in the United States, with a refining capacity of over 500,000 barrels of crude oil per day. The plant is also one of the largest employers in the area (its workforce included about 1,300 employees and 900 contractors in 2010) (18). Other major industrial employers include BASF Wyandotte Corporation, Georgia Gulf Corporation, and Dow Chemical Company, which is the largest employer in Iberville and West Baton Rouge parishes with more than 3,000 employees and contractors (19, 20). The chemical plants are key to the region's economy, offering good salary jobs even for workers with only a basic education (14).

However, the level of pollution in the region is relatively high, and so there is a "longstanding concern about the environmental problems and potential adverse health effects for residents" (21). Even though the state generated less than 7% by value of all U.S. chemicals in 2006, it reported almost 13% of all hazardous waste produced nationally. In fact, the plants along the corridor produce about a hundred major chemicals, including known carcinogens (16). The Baton Rouge MSA in particular, accounted for 10.5% out of the approximately 155 million pounds of toxic chemicals released in Louisiana in 2000 (as reported under the EPA Toxic Release Inventory Program).

This area is also affected by severe storms and multiple flooding events, which increases its biophysical vulnerability. Borden et al. (2007) compared the level of vulnerability to environmental hazards across 132 U.S. cities and found that Baton Rouge scored the highest on what they called the "natural hazards vulnerability index", a measure of vulnerability from "the historical frequency of hazard events and their impacts", characterized by weather-related human casualties, property losses, and hazard diversity and frequency, among other factors. The study also ranked the urban areas based on their "overall place vulnerability", an aggregate measure of social, built environment, and natural hazards vulnerabilities. Based on this analysis, Baton Rouge was designated as the second most vulnerable city in the U.S. (4).

Chapter 4
Data

Through a survey of relevant literature, Cutter et al. (2003) identified the major factors characterizing social vulnerability and defined a set of variables to empirically capture these characteristics. For the Baton Rouge MSA, a total of 29 socioeconomic variables were used in the analysis. The data were collected from the U.S. Census for the year 2000 for all 83 zip codes comprising the study area.

Additionally, a widely used indicator of environmental quality was included in the study, the Toxic Release Inventory (TRI) total annual chemical release and on-site and off-site disposal for 2000 from the Environmental Protection Agency (EPA) TRI Explorer database. This variable was collected at the zip code level. For those zip codes for which TRI data were not reported (missing values), a value of zero pounds of toxic chemicals reported was assumed. It is important to point out missing TRI data do not imply facilities have not used or released toxic or hazardous chemicals; missing values arise because facilities in a particular zip code did not meet all the criteria for reporting (22). Under section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA), a facility must submit a TRI report if it meets all three threshold criteria, namely, "if it has 10 or more full time employee equivalents; is included in a covered North American Industry Classification System (NAICS) code; and exceeds the manufacturing, processing, or otherwise use threshold under EPCRA §313 (40 CFR 372.25)" (23). In order to measure the spatial component of the TRI distribution, the inverse distance weighted interpolation method was used. The reasoning behind the proposed method is that the effect of pollutants is not restricted to the original zip code area units. A zip code area might have low TRI values by itself, but it would be affected by being adjacent to a zip code area with a high TRI value. The cartographic boundary files at the zip code level for the year 2000 were downloaded from the U.S. Census website (24) and analyzed using ArcGIS 9.2. The spatial reference system used was NAD83 and the projection was made using UTM zone 15. The list of socioeconomic and environmental variables is outlined in Table 4.1.

Table 4.1: Variables used in the analysis.

Variable Name	Description
Socioeconomic Variables⋆	
PCTBLACK	Percent African American, 2000
PCTINDIAN	Percent Native American, 2000
PCTASIAN	Percent Asian, 2000
PCTHISPA	Percent Hispanic or Latino, 2000
PCTFOREIGN	Percent foreign-born population, year of entry 1995 to March 2000
MEDAGE	Median age, 2000
PCTKID	Percent population under 5 years, 2000
PCTOLD	Percent population over 65 years, 2000
PCINCOME	Per capita income (in dollars), 1999
PCTHH75	Percent households earning more than $75,000, 1999
PCTPOVER	Percent population living below poverty level, 1999
PCTHHSS	Percent households with social security income, 1999
HOUSESQM	Number of housing units per square mile, 2000
PCTMOBILE	Percent housing units that are mobile homes, 2000
PCTRENTER	Percent renter occupied housing units, 2000
MEDRENT	Median gross rent for renter-occupied housing units (in dollars), 2000
MEDHOUSVAL	Median value of owner-occupied housing units (in dollars), 2000
PCTLABOR	Percent population 16 years and over in the labor force, 2000
PCTUNEMPL	Percent civilian labor force unemployed, 2000
PCTFEMLAB	Percent females participating in civilian labor force, 2000
PCTSERVICE	Percent employed in service occupations, 2000
PCTEXTRACT	Percent employed in primary extractive industries, 2000
PCTTRANS	Percent employed in transportation, warehousing, and utilities, 2000
PCTURBAN	Percent urban population, 2000
PCTFEM	Percent females, 2000
PCTFEMHH	Percent female householder families, no husband present, 2000
AVEHHSIZE	Average household size, 2000
PCTNOHIGH	Percent population 25 years and over with no high school diploma, 2000
PCHEALTH	Per capita number of health care and social assistant establishments, 2000
Environmental Variable†	
TRISQM	Average TRI reported disposed or released chemicals in pounds per square mile, 2000

⋆ Source: U.S. Census.

† Source: EPA.

Chapter 5
Identifying the Latent Components of Social Vulnerability in the Baton Rouge MSA

5.1 Methodology

In order to identify the social burdens of risk in the United States and to examine the spatial patterns of social vulnerability to natural hazards, Cutter at al. (2003) created the Social Vulnerability Index (SVI) based on a set of 42 socioeconomic variables for the year 1990 at the county level, the unit of analysis (12). In the present study, however, the objective is to study social vulnerability in the Baton Rouge MSA at the zip code level for the year 2000. The question then arises on the applicability of Cutter's methodology to the present analysis given the differences in scale and variable selection (since the availability of the data may differ according to the unit of analysis). In this regard, Schmidtlein et al. (2008) examined the sensitivity of the quantitative features of the SVI created by Cutter et al. (2003) to changes in the scale at which it is applied and the set of variables used in its construction. They found that across scales, the identification of the underlying drivers of social vulnerability remained fairly constant within a particular study area. With respect to the adequacy of variable selection, the results showed that the full set of variables used in the original SVI as well as the subset of variables provided similar results in the representation of vulnerability and the identification of highly vulnerable study units. Overall, the SVI approach was found to be fairly robust to minor changes in scale and variable selection (12), and so it was applied to study the social vulnerability of Greater Baton Rouge.

In order to define the underlying dimensions of social vulnerability from a large set of variables, Cutter et al. (2003) proposed the use of principal components analysis (PCA), a statistical technique used to reduce a large number of variables into a smaller number of components, called

principal components, that account for a high percentage of the variation in the observed data (4). This method allows the identification of the potential latent components or conceptual dimensions of social vulnerability from the 29 socioeconomic variables collected for the Baton Rouge MSA.

The set of 29 variables was subjected to PCA by using the statistical package SAS 9.3, which standardizes all variables prior to the analysis. The principal axis method using ones as prior communality estimates was used for the initial extraction of the components. In order to determine the number of meaningful components to retain, the eigenvalue-one criterion, also known as Kaiser criterion, was initially employed. An eigenvalue equates the amount of variance accounted for by a component. Since the observed variables were standardized (variance equals 1), any component with an eigenvalue greater than 1 explains a greater amount of variance than any of the original variables, and so is deemed worthy of being retained (25). The first eight components displayed eigenvalues greater than 1, accounting for 83.4% of the total variance (Appendix B).

Alternatively, the scree plot was examined to aid in the selection of components. Significant drops or "breaks" in eigenvalues indicate possible thresholds for component extraction (26). The scree plot suggested that either the first eight or the first six components were meaningful to retain (Appendix C). The first six components accounted for 74.9% of the total variance. Varimax (orthogonal) rotation was applied to both the eight-component and six-component solutions to facilitate the interpretation of the underlying dimensions of social vulnerability. This method minimizes the number of variables that have high loadings on more than one component, while maintaining the percentage of the total variance accounted for by the retained components (27). The resulting rotated components are uncorrelated, so the loadings equate bivariate correlations between the retained components and the original variables (25). Next, to interpret the rotated solutions, variables with high loadings for each component were identified (generally those having an absolute value greater than 0.5) (Appendix D). Examination of the commonalities among high loading variables resulted in the determination of the nature of the components, that is, the conceptual dimensions of social vulnerability. The six-component solution provided a better interpretation and so it was used in subsequent analysis.

5.2 Results and Analysis

The social vulnerability of the Baton Rouge MSA was characterized by the six components retained after PCA based on the criteria described above. These components explained 74.9% of the variation in the observed data (Table 5.1).

Table 5.1: Latent components of social vulnerability in the Baton Rouge MSA.

Component	Component Interpretation	Percent Variation Explained (after Rotation)	Dominant Variables	Correlation
1	Poverty	20.2	Percent population living below poverty level 1999	0.87 0.87
			Percent African American	0.83
2	Urbanization	15.4	Number of housing units per square mile	0.86
			Percent housing units that are mobile homes	-0.84
3	Elderly	11.0	Percent population over 65 years	0.83
			Median age	0.70
4	Affluence	10.9	Per capita number of health care and social assistant establishments	0.84 0.84
			Median value of owner-occupied housing units	0.69
5	Female and children	9.6	Percent females	0.90
			Percent population under 5 years	0.80
6	Race and ethnicity	7.7	Percent Native American	0.79
			Percent foreign-born population 1995 to 2000	0.65

Component 1: Poverty

In the first component, the two highest loading variables are the percent population living below poverty level and the percent African American population. The fact that both variables related to the same component is not surprising, since marked racial differences in socioeconomic status persist in the area. In Greater Baton Rouge, the percentage of African Americans living below the poverty level in 1999 was 30.6%, whereas for Whites it was 9.1%. The first component also correlated highly with per capita income in 1999, which for African Americans was roughly half of the per capita income for Whites. Poverty is a primary contributor of social vulnerability

as fewer individual and community resources are available to cope and recover from hazard impacts (6). While in absolute terms the economic losses of poor communities may be fewer, these communities tend to recover more slowly and many “never fully regain pre-impact levels, increasing their vulnerability to future hazards” (7).

Component 2: Urbanization

The second component identifies the level of urbanization and density of the built environment, where the most dominant variables include the number of housing units per square mile (which loaded positively) and the percent housing units that are mobile homes (which loaded negatively). Densely populated areas often suffer greater social and economic disruptions from hazard events, including significant structural loses and a potentially more complicated displacement of the affected population (6).

Component 3: Elderly

This component is measured primarily by the percent population over 65 years, the median age, and the percent households with social security income in 1999, all of which loaded positively. Age is an important demographic factor in describing social vulnerability. Older populations tend to be more vulnerable, not only because of health complications and difficulties in their mobility (in the case of evacuations), but also due to increasing economic insecurity (9).

Component 4: Affluence

Wealthier communities have better opportunities to “absorb and recover from losses more quickly due to insurance, social safety nets, entitlement programs” (6), and political power. In this study, this component is measured primarily by the per capita number of health care and social assistant establishments and the median value of owner-occupied housing units, both of which loaded positively.

Component 5: Female and Children

The fifth component is characterized by the percent female population and the percent population under five years of age. In most societies women are especially vulnerable, often due to family and gender specific responsibilities, sector specific employment, and lower wages, which limit their autonomy and access to resources (6). Also, families with children are likely to encounter greater obstacles when responding to hazard events (7).

Component 6: Race and Ethnicity

Racial or ethnic minority groups are often socially and economically marginalized, which affects their resilience, response, and recovery from the impact of hazards. In most cases, these groups are excluded from community planning, mitigation, and preparation activities. This problem is exacerbated by language and cultural barriers, as well as mainstream prejudices (7). Overall, in relationship to the other dimensions of vulnerability, the race and ethnicity component may be the least important in Greater Baton Rouge due to the very low percentage of minorities in the area (excluding African Americans). This component correlated highly with percent Native Americans (the median for the Baton Rouge MSA is 0.2%), percent foreign-born population that entered the United States between 1995 and 2000 (the median is 0.1%), and percent Hispanics (the median is 1.2%). As expected, the highest percentage of foreign-born population and to a lesser extent of Hispanics was found in the areas surrounding Louisiana State University, probably due to the presence of international students and faculty.

Chapter 6
Determining the Spatial Distribution of Social Vulnerability in the Baton Rouge MSA

6.1 Methodology

6.1.1 Calculating the Social Vulnerability Index

Principal components analysis (PCA) allows for the creation of a component score for each observation on every principal component. A component score is a linear combination of optimally-weighted observed variables, where the weights are calculated from the eigenvectors. The weights are said to be optimal since they produce a set of components that is the most successful in explaining the variance in the observed variables and that satisfy the principle of least squares (25, 28). Equation (6.1) gives the general formula for a component score (modified from 25).

$$C_{ij} = \sum_{k} a_{jk} \, X_{ik} \ , \tag{6.1}$$

where

i = subject or observation ,

j = component ,

k = observed variable ,

C_{ij} = component score for subject i on component j ,

a_{jk} = weight for observed variable k, as used in creating component j (after rotation) ,

X_{ik} = value of observed variable k for subject i .

In SAS, the component scores are calculated as a linear combination of the products between the weights from the rotated solution (the "standardized scoring coefficients") and the standardized variables. In this study, there were 83 observations (83 zip codes), each having a unique set of six component scores (Appendix E).

Next, the methodology proposed by Cutter et al. (2003) in the construction of the social vulnerability index was followed. Each component was examined to determine its overall influence on vulnerability, that is, if they have a tendency to increase or decrease social vulnerability. This was done by looking at the signs and the representation of the high loading variables in each component. Based on this criterion, a directional adjustment (cardinality) was applied to the entire component so that positive values indicated a tendency to increase vulnerability and negative values to decrease vulnerability. For example, if a component exhibited positive high loadings for variables that would contribute to decreased vulnerability, a negative cardinality was applied, and so the component was multiplied by -1. Alternatively, those components in which the signs of the high loading variables were consistent with their contribution to social vulnerability (a positive sign if they increased vulnerability or a negative sign if they decreased vulnerability) retained a positive cardinality since no adjustment was needed. For components where the influence of the variables was ambiguous, the absolute value was used (Appendix F). Finally, the social vulnerability index score for each zip code was computed by placing its component scores, adjusted for directionality, into an additive linear model with equal weights (26,29). The calculation is indicated in Equation (6.2).

$$SV_i = \sum_j C'_{ij} \; , \tag{6.2}$$

where

SV_i = social vulnerability index score for observation i ,

C'_{ij} = component score for subject i on component j after directional adjustment .

Even though the social vulnerability index is effective in quantifying the relative levels of social vulnerability over time and across geographic boundaries, its validation presents a challenging task since vulnerability is a function of multiple and complex factors, so no variable has yet been identified against which to validate the index in full (12). For this reason, instead of testing the reliability of the index for the Baton Rouge MSA, the present study relies on the findings of Schmidtlein et al. (2008), who assessed the robustness of the SVI developed by Cutter et al. (2003) to changes in its construction. The results showed that within a particular geographic area, the overall representation of vulnerability remained fairly constant to changes in variable selection as well as scalar changes.

6.1.2 Mapping Social Vulnerability

In order to determine the relative vulnerability for each zip code and the spatial variation of vulnerability for the Greater Baton Rouge area, the social vulnerability index scores were mapped based on standard deviations from the mean, with five categories ranging from less than -1 (least vulnerable) to greater than 1 (most vulnerable). Two potential clusters of social vulnerability were found, one for the least vulnerable and other for the most vulnerable category. To confirm these findings, a hot spot analysis was also performed (30). This statistical spatial technique is used to identify clusters of points with higher or lower values than expected by random chance alone by looking at each unit of analysis in the context of neighboring units (31).

6.2 Results and Analysis

The social vulnerability index scores for each zip code in the Greater Baton Rouge area, sorted from the least to the most vulnerable, are shown in Appendix G. The scores range from -5.91 (least vulnerable) to 9.70 (most vulnerable). The mean score for the area is 1.24 and the standard deviation is 2.33. The index scores are relative measures of social vulnerability, applicable only to a particular study area, and do not represent "individually based levels of vulnerability" (12). Thus, the importance of the social vulnerability index is not in its absolute value, but in "its

comparative value across geographic locations" (1). The spatial variability of social vulnerability in the Baton Rouge MSA is presented in Figure 6.1.

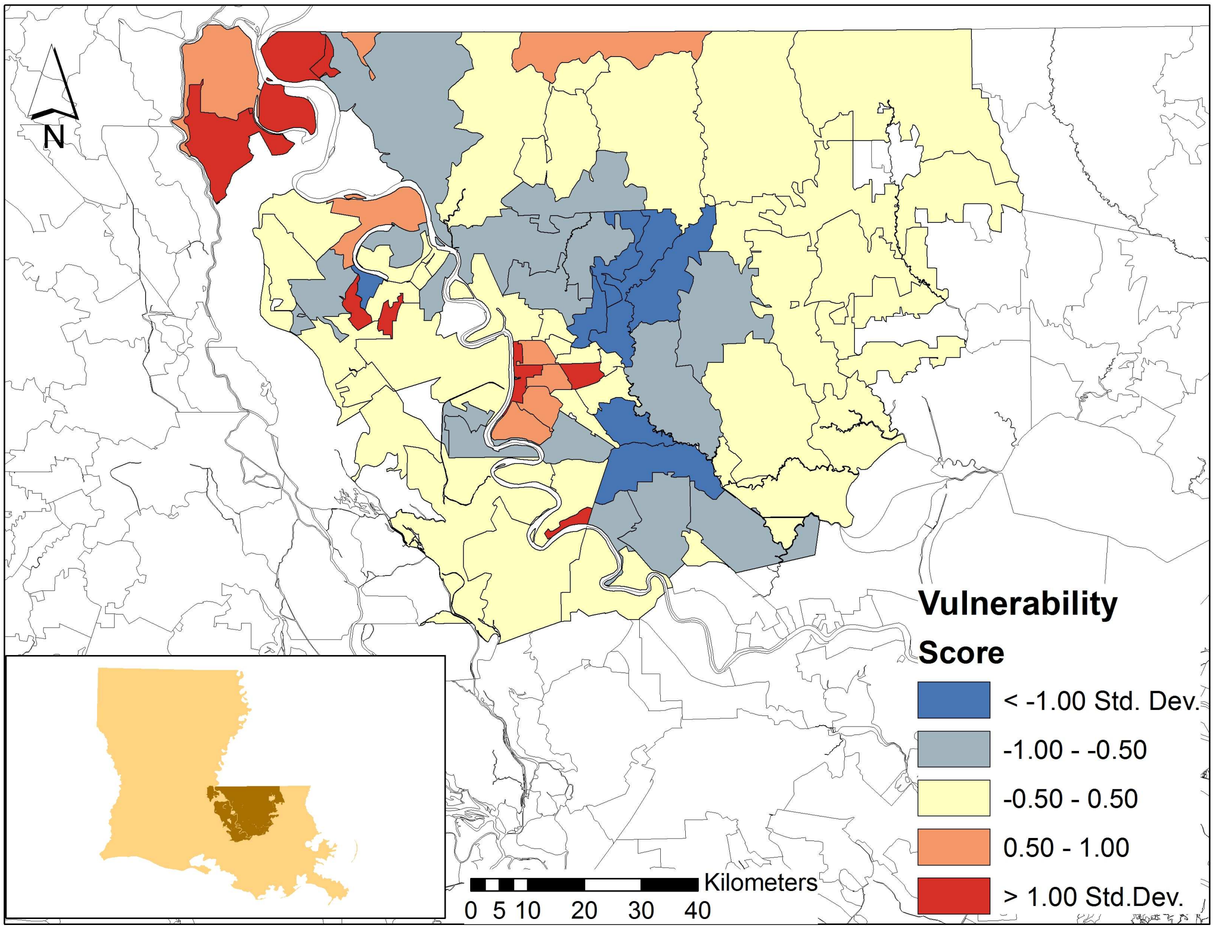

Figure 6.1: Spatial distribution of social vulnerability in the Baton Rouge MSA at the zip code level.

Approximately 50.6% of the total number of zip codes exhibit moderate levels of social vulnerability (from -0.5 to 0.5 standard deviations from the mean), and about 19.3% are classified as having low social vulnerability (from -1 to -0.5 standard deviations from the mean). Potential clusters of least and most vulnerable zip codes are also evident, an observation that was confirmed through the hot spots analysis (Figure 6.2).

The least vulnerable zip codes (less than -1 standard deviations from the mean) representing 9.6% of the total, are mostly clustered in the center of the Greater Baton Rouge area. All of them except one zip code, 70801, are fairly homogenous, exhibiting low values for the poverty component (mainly due to a high percent of households earning more than $75,000 a year, and

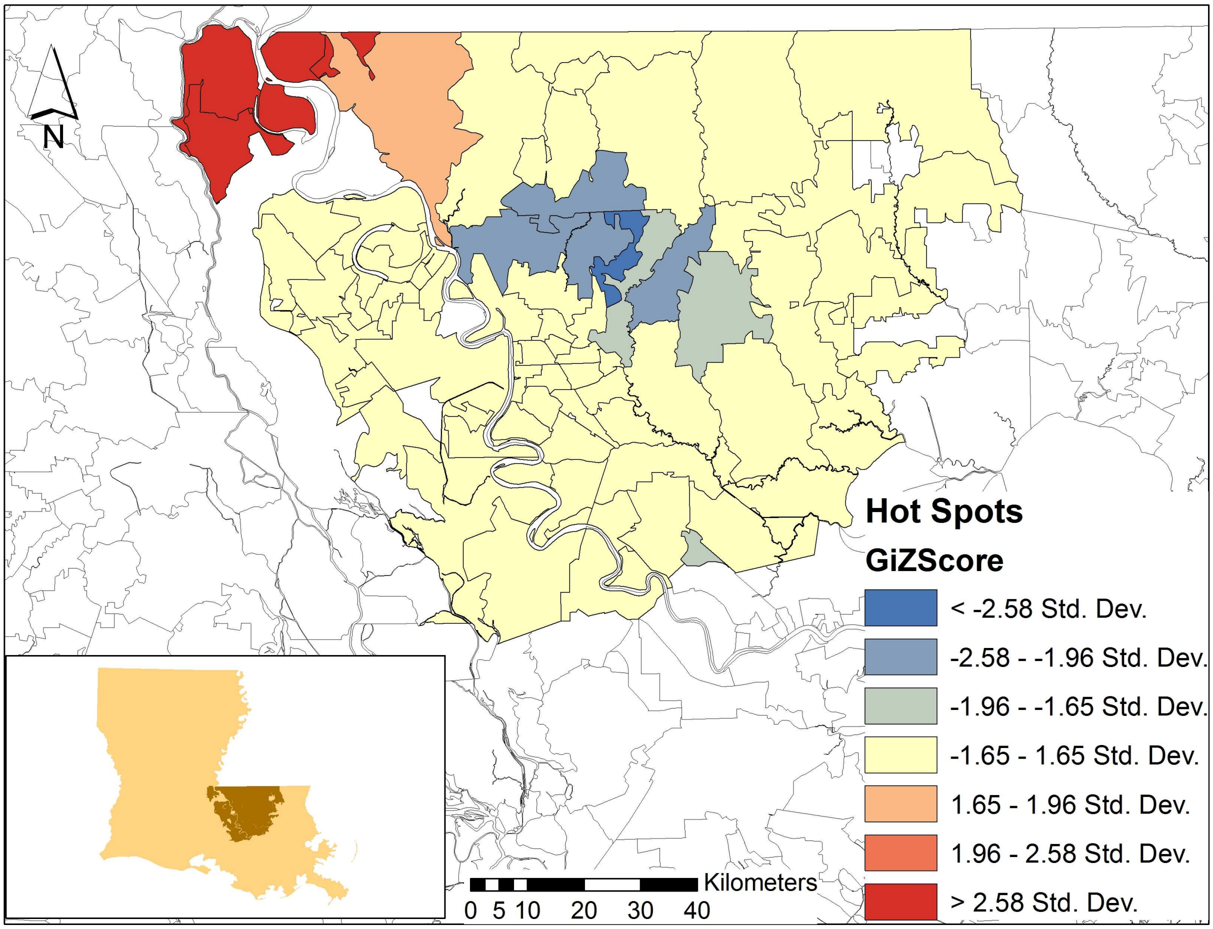

Figure 6.2: Hot spots analysis.

low percentages of African Americans and of people living below the poverty line), as well as low values for the elderly component, characteristics that in fact decrease social vulnerability.

The least vulnerable zip code is 70801. It is located in East Baton Rouge parish, in the eastern part of downtown Baton Rouge. It has an area of only 0.1 square miles and a population of 88 people (as reported in the year 2000), yet it contains a large number of government and commercial buildings, and the highest number of manufacturing facilities per square mile in the Baton Rouge MSA (about 18 facilities per square mile). This zip code was classified as the least vulnerable given it has the highest per capita number of health care and social assistant establishments and a high median house value, even though it also has a large percent of poor and African American populations.

On the other hand, 10.8% of the total number of zip codes are classified as the most vulnerable (those with index scores greater than 1 standard deviations from the mean). They are located

in the western part of the Baton Rouge MSA, mostly clustered in the northwest. They include mostly rural areas with low income populations, high percent of African Americans, and high percent of the population over 25 with no high school diploma (ranging from 12% to 76%, as reported in the year 2000). Most zip codes in this category also exhibit high percentages of female headed households, mobile homes, and households receiving social security income.

The most socially vulnerable zip code is 70782, located in Tunica, West Feliciana. This is a rural area, where in 2000, about 23% of the population (out of a total of 201) lived below the poverty level, and 30% of the population over 25 lacked high school diploma, yet exhibited 0% unemployment. This zip code is classified as the most vulnerable mainly due to its high value for the ethnicity component (the percentages of Hispanic and foreign born population were above the Baton Rouge MSA average).

Chapter 7
Studying the Relationship between Social Vulnerability and Environmental Pollution

7.1 Methodology

First, multiple regression analysis was performed to determine the extent of the relation between the six principal components of social vulnerability obtained through PCA and the indicator of environmental pollution, namely, the average TRI reported disposed or released chemicals in pounds per square mile (TRISQM). The natural logarithm of (TRISQM + 1) was calculated, so the transformed mean was assumed to follow the linear model given in Equation (7.1). Since the final rotated components are uncorrelated, multicollinearity is not a problem in the analysis.

$$\ln(\text{TRISQM}_i + 1) = b_0 + \sum_{j=1}^{6} b_j \, C_{ij} \; , \tag{7.1}$$

where

TRISQM_i	=	average TRI reported disposed or released chemicals in pounds per square mile for subject i ,
b_j	=	estimated regression coefficients ,
C_{ij}	=	component scores for subject i on components $j = 1 \ldots 6$ as calculated in Equation (7.1) .

Since all components are uncorrelated, a reduced model was obtained by removing non-significant components at the 0.05 level. Backward elimination was performed to confirm these results.

Second, a simple Pearson correlation was conducted to test the association (or lack thereof) between the average TRI per square mile (TRISQM) and the social vulnerability index scores for each zip code.

Finally, to determine the spatial variation of toxic emissions in the Baton Rouge MSA at the zip code level, the TRISQM values were mapped by dividing the data into quintiles.

7.2 Results and Analysis

For the multiple regression, a significant model was found (P=0.0003) relating pollution, based on TRI data, and the components of social vulnerability in the Baton Rouge MSA. In the present study, the qualitative nature of these relationships is of importance, rather than their qualitative values. Table 7.1 shows the estimated regression coefficients and their respective P values.

Table 7.1: Multiple regression parameter estimates.

Variable	DF	Parameter Estimate	Standard Error	t Value	P Value (P > |t|)
Intercept	1	7.154	0.269	26.58	<0.0001
Component 1: Poverty	1	0.240	0.271	0.89	0.3781
Component 2: Urbanization	1	1.004	0.271	3.71	0.0004
Component 3: Elderly	1	-0.913	0.271	-3.37	0.0012
Component 4: Affluence	1	0.202	0.271	0.75	0.4577
Component 5: Female and children	1	0.460	0.271	1.70	0.0932
Component 6: Race and ethnicity	1	0.050	0.271	0.19	0.8536

The final reduced model, after the elimination of non-significant components at the 0.05 level, is given in Equations (7.2) and (7.3).

$$\ln(\mathrm{TRISQM}_i + 1) = 7.154 + 1.004\, C_{i2} - 0.913\, C_{i3}\,, \tag{7.2}$$

$$\ln(\mathrm{TRISQM}_i + 1) = 7.154 + 1.004\,(\mathrm{urbanization})_{\mathrm{i}} - 0.913\,(\mathrm{elderly})_{\mathrm{i}}\,. \tag{7.3}$$

The dependent variable correlates positively with urbanization (component 2) and negatively with the elderly (component 3). The results suggest a higher housing density in areas

of high levels of pollution, and thus a larger number of people may be exposed to the toxic chemicals emitted by the surrounding facilities. On the other hand, elderly populations seem to be located in less polluted areas, but the reasons for this occurrence are out of the scope of the study. To a lesser extent, pollution also related positively with component 5, female and children (P=0.0932). Interestingly, even though environmental justice studies have found that in many heavily industrialized communities, minority and economically vulnerable residents are disproportionately represented in neighborhoods closest to noxious facilities, the results showed no significant correlation between poverty (in which African American population was the second highest loading variable) and toxic emissions.

Furthermore, the association between average toxic emissions per square mile (TRISQM) and the social vulnerability index scores was found to be weak (r=0.01364), and non-significant (P= 0.9026). This result can be visualized by comparing the spatial distribution of social vulnerability (Figure 6.1) with the spatial distribution of the TRISQM in the Baton Rouge MSA at the zip code level (Figure 7.1).

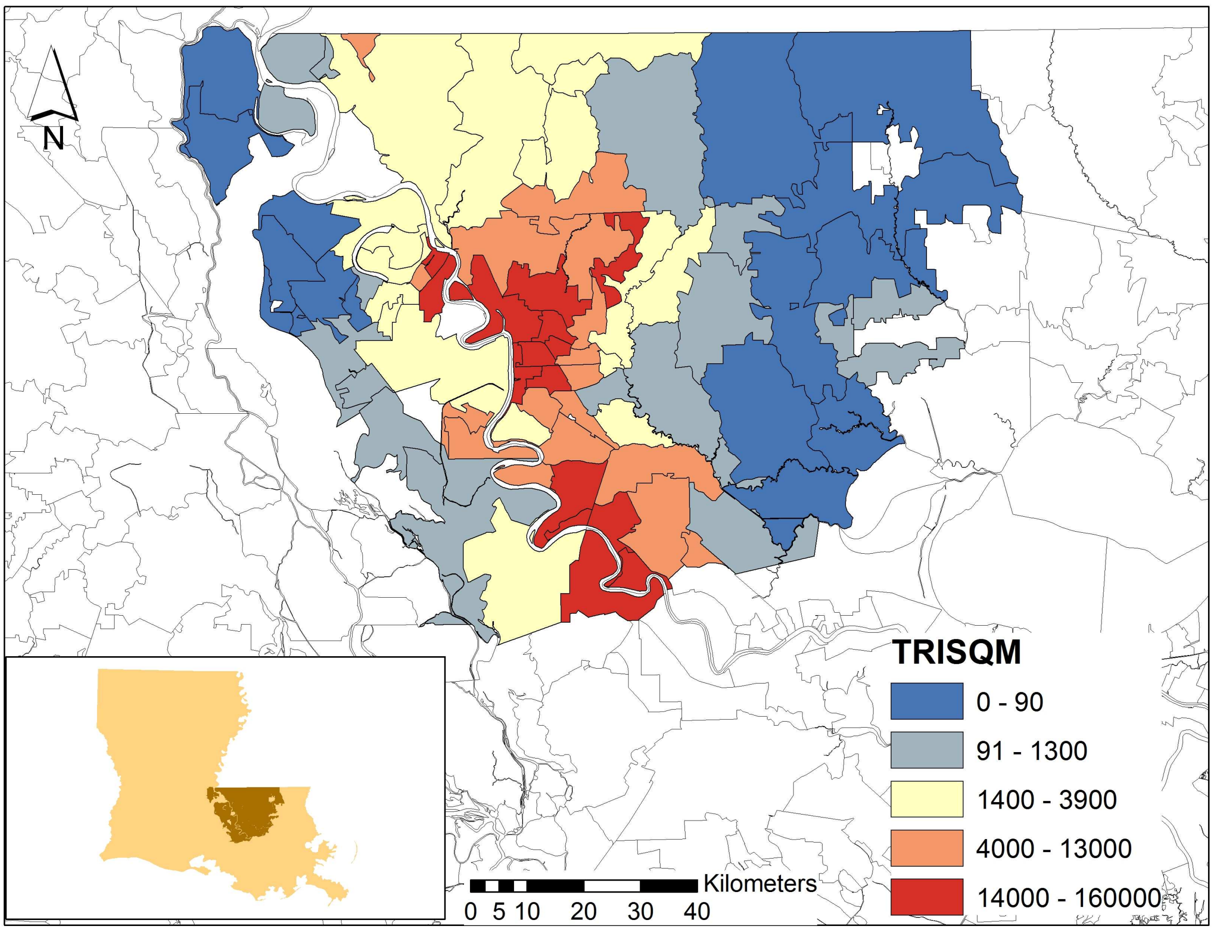

Figure 7.1: Spatial distribution of the average TRI reported disposed or released chemicals in pounds per square mile (TRISQM) in the Baton Rouge MSA at the zip code level.

Chapter 8
Summary and Conclusions

The systematic study of vulnerability helps understand the factors that put people and places at risk, and the conditions that reduce their ability to cope and recover from environmental threats (32). In particular, social vulnerability is born from the "unequal access to opportunities and unequal exposures to risks which are consequences of the socioeconomic system" (7).

In the present study, the underlying dimensions of social vulnerability in Louisiana's upper industrial corridor (the Baton Rouge MSA) were identified for the year 2000. A set of 29 socioeconomic variables collected at the zip code level was reduced to a smaller number of components through principal component analysis. Poverty (in which African American population was the second highest loading variable), urbanization, elderly, affluence, female and children, and race and ethnicity, were the six most relevant factors in explaining the social vulnerability of the area.

In addition, the spatial distribution of social vulnerability in the Baton Rouge MSA was determined. The identification of vulnerable areas is important when designing policy, mitigation, emergency preparedness, and recovery planning initiatives, which "must be place-specific and flexible in order to adjust to variability in physical parameters and social characteristics" (33).

In order to determine this distribution, the social vulnerability index proposed by Cutter et al. (2003) was calculated to quantify the relative levels of vulnerability across the area. Approximately 51% of the total number of zip codes exhibited moderate levels of social vulnerability (from -0.5 to 0.5 standard deviations), 19% were classified as having low social vulnerability (from -1 to -0.5 standard deviations), and 10% as having high social vulnerability (from 0.5 to 1 standard deviations). The least vulnerable zip codes (less than -1 standard deviations) represented about 10% of the total, and the most socially vulnerable (greater than 1 standard deviations) approximately 11%.

Second, the social vulnerability index scores for each zip code were mapped based on standard deviations from the mean. Two potential clusters of vulnerability were found: the least

vulnerable zip codes were clustered mostly in the center of the region, and the most vulnerable zip codes were located in the western part of the Baton Rouge MSA, clustered in the northwest. These results were confirmed through the hot spots analysis statistical spatial technique.

It is important to note that the social vulnerability index is useful as a rough assessment "of the distribution and likely impact of hazards and disasters", and that "its utility is exploratory and diagnostic in nature", enabling to quantify the relative levels of vulnerability within a particular area (34). The validation of the index is a major challenge since at this time no precise outcome measure has been identified yet. For this reason, the representation and the spatial distribution of vulnerability produced by the index must be coupled with expert guidance to ensure the results are "reasonable and consistent with locally based geographic knowledge of the study area" (12).

Another important dimension of community attributes and resources is the quality of the local environment. The Baton Rouge MSA is a highly industrialized region, home to numerous chemical and petrochemical facilities, with relatively high levels of pollution. In fact, the area accounted for 10.5% of all toxic chemical releases in Louisiana in 2000 (as reported under EPA's TRI program). Concerns about the inequitable distribution of the burdens of toxic emissions and their adverse health effects are longstanding issues in the region (21). In this particular area of prevalent cumulative pollution, the nature of the associations between social vulnerability and potential exposure to toxic chemical releases was examined at the zip code level for the year 2000. No significant correlation was found between TRI emissions and the overall social vulnerability index scores for the Baton Rouge MSA.

In addition, the extent of the relation between the six principal components of social vulnerability obtained through PCA and pollution was determined. Pollution, as measured by total TRI emissions, related significantly with the urbanization and elderly components, and to a lesser extent with the female and children component. Contrary to other environmental justice studies, which have found that poor and minority populations are disproportionately represented in heavily polluted areas, the study found no significant correlation between toxic emissions and poverty (in which African American population was the second most important variable).

Finally, the results of the study may serve as benchmarks to examine the changes in the nature and spatial distribution of social vulnerability and exposure conditions to environmental pollution over time. In this sense, this study can help researchers and community stakeholders to understand whether these are transient phenomena, or whether they reflect a chronic state, intrinsic of this heavily industrialized area of Louisiana.

References

1. *Temporal and spatial changes in social vulnerability to natural hazards.* **Cutter, Susan L. and Finch, Christina.** 2008, Proceedings of the National Academy of Sciences, Vol. 105, pp. 23012306.

2. *Vulnerability: A generally applicable conceptual framework for climate change research.* **Fussel, Hans-Martin.** 2007, Global Environmental Change, Vol. 17, pp. 155167.

3. *Assessing the Vulnerability of Social-Environmental Systems.* **Eakin, Hallie and Luers, Amy Lynd.** 2006, Annual Review of Environment and Resources, Vol. 31, pp. 36594.

4. *Vulnerability of U.S. Cities to Environmental Hazards.* **Borden, Kevin A., et al.** 2007, Journal of Homeland Security and Emergency Management, Vol. 4.

5. **United Nations.** *2009 UNISDR Terminology on Disaster Risk Reduction.* Geneva : United Nations International Strategy for Disaster Reduction, 2009.

6. *Social Vulnerability to Environmental Hazards.* **Cutter, Susan L., Boruff, Bryan J. and Shirley, W. Lynn.** 2003, SOCIAL SCIENCE QUARTERLY, Vol. 84, pp. 242-261.

7. *Identifying and Mapping Community Vulnerability.* **Morrow, Betty Hearn.** 1999, Disasters, Vol. 23, pp. 1-18.

8. *Vulnerability to environmental hazards.* **Cutter, Susan L.** 1996, Progress in Human Geography, Vol. 20, pp. 529-539.

9. *Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina.* **Cutter, Susan L., Mitchell, Jerry T. and Scott, Michael S.** 2000, Annals of the Association of American Geographers, Vol. 90, pp. 713-737.

10. *Vulnerability.* **Adger, W. Neil.** 2006, Global Environmental Change, Vol. 16, pp. 268281.

11. *A place-based model for understanding community resilience to natural disasters.* **Cutter, Susan L., et al.** 2008, Global Environmental Change, Vol. 18, pp. 598606.

12. *A Sensitivity Analysis of the Social Vulnerability Index.* **Schmidtlein, Mathew C., et al.** 2008, Risk Analysis, Vol. 28, pp. 1099-1114.

13. **U.S. Census Bureau.** U.S. Census Bureau. *Metropolitan and micropolitan statistical areas and components, December 2009, WITH CODES.* [Online] Septmeber 2010. [Cited: May 25, 2011.] `http://www.census.gov/population/www/metroareas/lists/2009/List1.txt` .

14. *The Rusting of the Chemical Corridor.* **Colten, Craig E.** 2006, Technology and Culture, Vol. 47, pp. 95-101.

15. **Allen, Barbara L.** *Uneasy Alchemy. Citizens and Experts in Louisiana's Chemical Corridor Disputes* . s.l. : The MIT Press, 2003.

16. *Cradle of a Revolution? The Industrial Transformation of Louisianas Lower Mississippi River.* **Allen, Barbara L.** 2006, Technology and Culture, Vol. 47, pp. 112-119.

17. **Baton Rouge Area Chamber.** Vital Statistics: Businesses & Industries. [Online] 2011. [Cited: June 7, 2011.] `http://www.brac.org/site31.php` .

18. **ExxonMobil.** ExxonMobil. *ExxonMobil Refining & Supply.* [Online] [Cited: June 8, 2011.] http://www.exxonmobil.com/NA-English/Files/2011_BRRF_Fact_Sheet.pdf .

19. **City of Baton Rouge. Office of the Planning Commission.** Facts about Baton Rouge. [Online] [Cited: May 23, 2011.] http://brgov.com/dept/planning/facts.htm#Top .

20. **DOW.** Dow in Louisiana - Louisiana Operations. [Online] [Cited: June 12, 2011.] http://www.dow.com/louisiana/locations/plaquemine.htm .

21. *An examination of race and poverty for populations living near industrial sources of air pollution.* **Perlin, Susan A., Sexton, Ken and Wong, David W.S.** 1999, Journal of Exposure Analysis and Environmental Epidemiology, Vol. 9, pp. 2948.

22. **Wakeland, Mort.** Personal communication. EPCRA 313 *Enforcement, and TRI Program Coordinator.* May 24, 2011.

23. **EPA.** Toxics Release Inventory (TRI) Program. [Online] 2011. [Cited: April 5, 2011.] http://tri.supportportal.com/ics/support/splash.asp?deptID=23021 .

24. **U.S. Census Bureau.** Cartographic Boundary Files. [Online] 2011. [Cited: April 30, 2011.] http://www.census.gov/geo/www/cob/z52000.html .

25. **Hatcher, Larry.** *A Step-by-Step Approach to Using the SAS System for Factor Analysis and Structural Equation Modeling.* 1. Cary : SAS Institute Inc., 1994.

26. **Hazards and Vulnerability Research Institute.** Hazards and Vulnerability Research Institute. *The SoVI Recipe.* [Online] January 2011. [Cited: June 4, 2011.] http://webra.cas.sc.edu/hvri/docs/sovi_32_recipe.pdf .

27. **Norusis, Marija.** *SPSS 12.0 Statistical Procedures Companion.* Upper Saddle River : Prentice Hall, 2003.

28. **Suhr, Diana D.** SAS. *Paper 203-30. Principal Component Analysis vs. Exploratory Factor Analysis.* [Online] [Cited: June 5, 2011.] http://www2.sas.com/proceedings/sugi30/203-30.pdf .

29. **Hazards and Vulnerability Research Institute.** Hazards and Vulnerability Research Institute. *The SoVI Recipe.* [Online] May 2008. [Cited: June 5, 2011.] http://webra.cas.sc.edu/hvri/docs/SoVIRecipe.pdf .

30. **Arenas, Helbert.** Personal communication. July 5, 2011.

31. **Environmental Systems Research Institute.** ArcGIS 9.2 Desktop Help. *Hot Spot Analysis (Getis-Ord Gi*) (Spatial Statistics).* [Online] 2009. [Cited: August 15, 2011.] http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Hot_Spot_Analysis_%28Getis-Ord_Gi*%29_%28Spatial_Statistics%29 .

32. *The Vulnerability of Science and the Science of Vulnerability.* **Cutter, Susan.** 2003, Annals of the Association of American Geographers, Vol. 93, pp. 112.

33. *Erosion Hazard Vulnerability of US Coastal Counties.* **Boruff, Bryan J., Emrich, Christopher and Cutter, Susan L.** 2005, Journal of Coastal Research, Vol. 21, pp. 932942.

34. *Social Science Perspectives on Hazards and Vulnerability Science.* **Cutter, Susan L.** 2010, Geophysical Hazards, pp. 17-30.

Appendix A. Copyright Permission

Figure A.1 shows the copyright permission to reproduce Cutter's hazards-of-place model of vulnerability, as published in the journal *Progress in Human Geography* in 1996 by Sage Publications, and replicated in Figure 2.1.

Figure A.1: Publisher's copyright permission to reproduce the hazards-of-place model of vulnerability proposed by Cutter (1996).

Appendix B. PCA: Eigenvalues of the Correlation Matrix (SAS)

Table B.1: PCA: Eigenvalues of the correlation matrix (SAS).

	Eigenvalue	Difference	Proportion	Cumulative
1	7.07182070	2.20678866	0.24390	0.2439
2	4.86503204	1.81038647	0.16780	0.4116
3	3.05464557	0.40864126	0.10530	0.5169
4	2.64600431	0.31872189	0.09120	0.6082
5	2.32728241	0.56835498	0.08030	0.6884
6	1.75892744	0.48190300	0.06070	0.7491
7	1.27702444	0.07598249	0.04400	0.7931
8	1.20104194	0.49827675	0.04140	0.8345
9	0.70276519	0.08474861	0.02420	0.8588
10	0.61801659	0.03227776	0.02130	0.8801
11	0.58573882	0.12150607	0.02020	0.9003
12	0.46423276	0.09724350	0.01600	0.9163
13	0.36698926	0.04849355	0.01270	0.9289
14	0.31849571	0.02703733	0.01100	0.9399
15	0.29145838	0.04816773	0.01010	0.9500
16	0.24329065	0.03994558	0.00840	0.9584
17	0.20334508	0.02772831	0.00700	0.9654
18	0.17561677	0.02810048	0.00610	0.9714
19	0.14751629	0.01637375	0.00510	0.9765
20	0.13114254	0.01832663	0.00450	0.9810
21	0.11281591	0.00336865	0.00390	0.9849
22	0.10944726	0.02444602	0.00380	0.9887
23	0.08500124	0.02013819	0.00209	0.9916
24	0.06486304	0.00743466	0.00220	0.9939
25	0.05742838	0.00959618	0.00200	0.9959
26	0.04783221	0.00995826	0.00160	0.9975
27	0.03787395	0.01656995	0.00130	0.9988
28	0.02130399	0.00825685	0.00070	0.9996
29	0.01304714		0.00040	1.0000

Appendix C. PCA: Scree Plot of Eigenvalues (SAS)

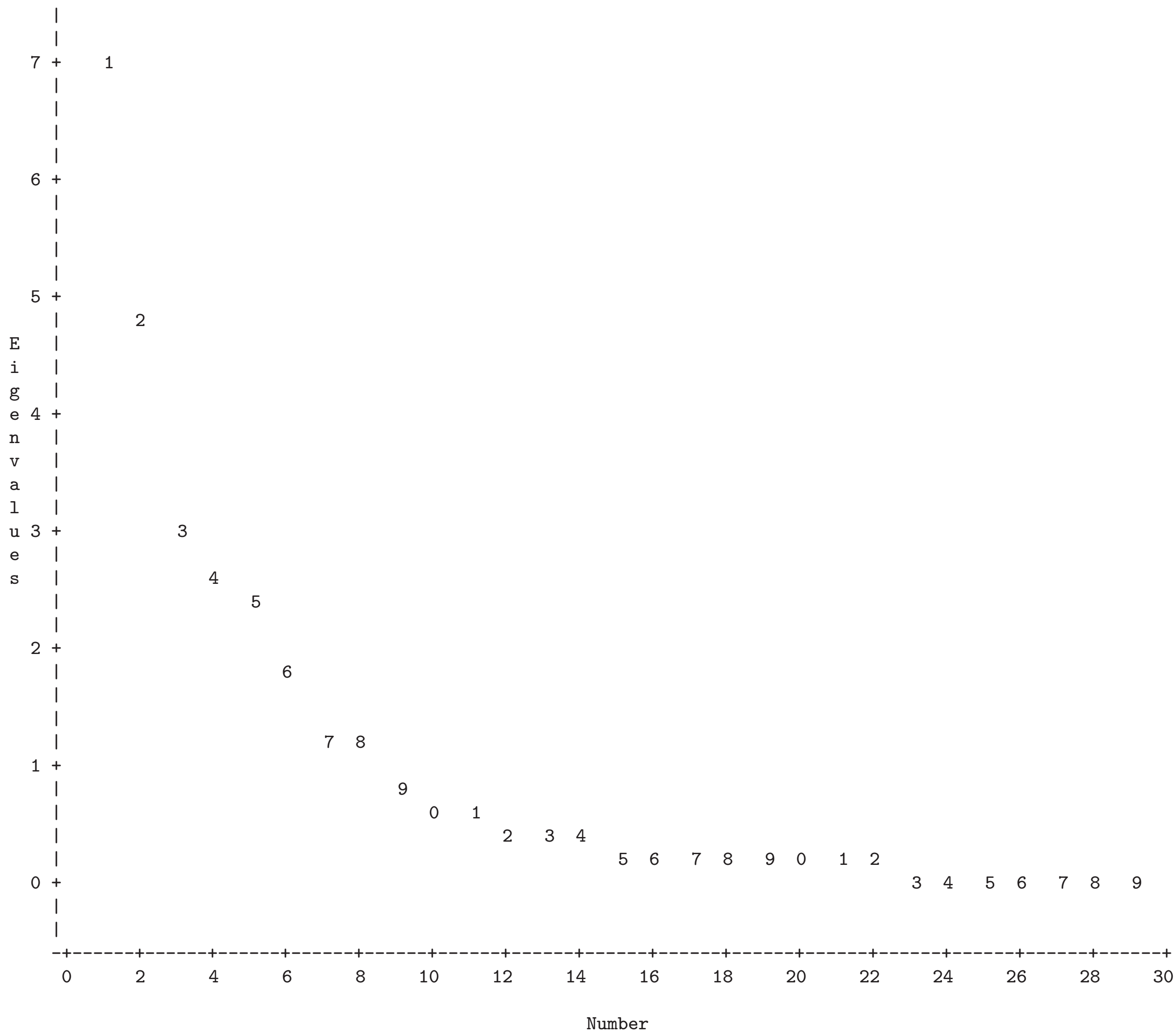

Figure C.1: PCA: Scree plot of eigenvalues (SAS).

Appendix D. PCA: Component Pattern after Varimax Rotation (SAS)

Table D.1: Six-component solution.

	Component 1	Component 2	Component 3	Component 4	Component 5	Component 6
PCTBLACK	0.83180	0.27167	-0.14641	-0.14701	-0.07521	-0.16376
PCTINDIAN	0.03512	-0.24097	-0.07496	0.11086	0.11683	0.78847
PCTASIAN	-0.20403	0.81120	0.06502	0.00653	-0.02436	0.22829
PCTHISPA	-0.09624	0.33271	-0.12076	0.15369	-0.09764	0.57898
PCTFOREIGN	-0.07821	0.52877	-0.11874	0.01108	0.02150	0.64505
MEDAGE	-0.16124	-0.32683	0.69693	0.10224	-0.28004	-0.09130
PCTKID	0.06989	-0.10755	-0.32018	0.16536	0.80379	-0.07198
PCTOLD	0.17128	0.11384	0.82978	-0.22733	0.18715	0.09351
PCINCOME	-0.80846	0.32176	0.03812	0.02730	0.05253	-0.06745
PCTHH75	-0.75551	0.26425	-0.14938	0.00835	0.16358	-0.19519
PCTPOVER	0.86579	0.05648	0.02645	0.07051	0.22602	0.08147
PCTHHSS	0.36323	-0.11779	0.62890	-0.37764	0.14244	-0.03979
HOUSESQM	-0.00677	0.85831	-0.03717	-0.00710	0.10114	0.07676
PCTMOBILE	0.07743	-0.83885	0.05602	-0.22624	-0.04249	0.15130
PCTRENTER	0.36188	0.58147	-0.26010	0.36871	-0.22980	0.38233
MEDRENT	-0.60915	0.35145	-0.25850	-0.27399	0.33131	0.01578
MEDHOUSVAL	-0.44933	0.28446	-0.18986	0.68660	0.03162	0.11262
PCTLABOR	-0.58615	0.14000	-0.22168	0.19137	0.60602	0.21785
PCTUNEMPL	0.68289	0.04053	0.03302	0.50326	0.11783	-0.24346
PCTFEMLAB	0.12261	0.08255	-0.59204	-0.21812	0.26066	0.21845
PCTSERVICE	0.44260	-0.01461	-0.39657	-0.52079	-0.36827	0.28159
PCTEXTRACT	0.43942	-0.13247	0.50036	0.19140	0.04381	-0.23443
PCTTRANS	-0.16614	-0.05785	0.29715	-0.22010	-0.12609	-0.21738
PCTURBAN	-0.14892	0.68486	-0.39263	0.19587	0.20114	-0.02256
PCTFEM	-0.06066	0.18097	0.25781	-0.19503	0.89616	0.04017
PCTFEMHH	0.66186	0.41167	-0.21651	-0.43040	0.21440	0.02691
AVEHHSIZE	-0.00577	-0.35293	-0.25112	-0.68245	0.07053	-0.40210
PCTNOHIGH	0.70086	-0.37203	0.07938	-0.12756	-0.47592	-0.07586
PCHEALTH	0.18372	0.05388	-0.17294	0.83721	0.01895	0.15522

Table D.2: Eight-component solution.

	Component 1	Component 2	Component 3	Component 4	Component 5	Component 6	Component 7	Component 8
PCTBLACK	0.81613	0.27069	-0.04001	-0.06027	0.03966	0.26206	-0.22996	-0.03003
PCTINDIAN	0.05246	-0.21968	0.13946	0.12943	-0.02327	0.08635	0.79772	-0.03773
PCTASIAN	-0.20903	0.81673	-0.01292	-0.06374	0.03737	-0.08827	0.24552	-0.03918
PCTHISPA	-0.08955	0.33790	0.22253	-0.08779	-0.07418	0.13148	0.55083	-0.00363
PCTFOREIGN	-0.05821	0.56207	-0.06706	0.00471	-0.14346	-0.05600	0.71107	-0.14024
MEDAGE	-0.24221	-0.39070	0.22377	-0.39079	0.62504	-0.18402	-0.19121	0.00603
PCTKID	0.09329	-0.07475	0.10211	0.87841	-0.20153	0.06950	-0.04330	0.00135
PCTOLD	0.09140	0.07105	-0.03692	0.04557	0.93784	-0.09780	-0.00352	0.10750
PCINCOME	-0.86585	0.29334	0.02906	-0.01505	0.03501	0.02032	-0.11067	-0.12042
PCTHH75	-0.81256	0.24697	-0.05731	0.11011	-0.13878	0.04510	-0.21500	-0.23041
PCTPOVER	0.79678	0.05672	0.05882	0.17371	0.16803	0.03517	0.03734	-0.38347
PCTHHSS	0.29492	-0.14592	-0.25146	0.01873	0.74574	-0.04149	-0.10168	0.01631
HOUSESQM	-0.01358	0.86186	0.03354	0.08778	0.03467	0.05533	0.05654	0.01949
PCTMOBILE	0.08415	-0.82684	-0.29083	-0.06171	0.02002	-0.03876	0.20436	-0.08749
PCTRENTER	0.34970	0.57630	0.46795	-0.19460	-0.17042	0.20799	0.30086	-0.10219
MEDRENT	-0.59436	0.37614	-0.35418	0.32445	-0.21342	0.08358	0.07520	-0.01616
MEDHOUSVAL	-0.43293	0.27913	0.64448	0.10087	-0.31279	-0.11697	0.10056	0.00246
PCTLABOR	-0.59568	0.14750	0.19850	0.62623	-0.11423	0.13126	0.19727	-0.00961
PCTUNEMPL	0.66392	0.04652	0.34747	0.13430	-0.08242	-0.32824	-0.21424	-0.29426
PCTFEMLAB	0.01442	0.05786	0.01281	0.22826	-0.10103	0.84610	0.01868	-0.32965
PCTSERVICE	0.42726	-0.01684	-0.30743	-0.36680	-0.08878	0.65890	0.18186	-0.01381
PCTEXTRACT	0.37863	-0.13513	-0.06681	-0.06667	0.26251	-0.62946	-0.14700	-0.46549
PCTTRANS	-0.01550	-0.03737	-0.11968	-0.00947	0.15270	-0.16621	-0.13556	0.87450
PCTURBAN	-0.15121	0.69648	0.15986	0.23672	-0.32816	0.12140	-0.03231	-0.11290
PCTFEM	-0.10833	0.18950	-0.19741	0.82002	0.42448	-0.04443	0.03880	-0.06321
PCTFEMHH	0.63135	0.42555	-0.33830	0.18848	0.07565	0.37089	-0.02145	-0.11864
AVEHHSIZE	0.04444	-0.32338	-0.72686	0.09991	-0.17945	0.18452	-0.32535	0.15454
PCTNOHIGH	0.70413	-0.37399	-0.12768	-0.48023	0.03793	-0.02404	-0.06975	-0.07135
PCHEALTH	0.17010	0.03270	0.91502	0.10041	-0.16732	0.04774	0.05384	-0.04082

Appendix E. Component Scores for Each Zip Code after Rotation (SAS)

Table E.1: Component scores for each zip code after rotation (SAS).

Zip Code	Component 1	Component 2	Component 3	Component 4	Component 5	Component 6
70346	0.95536	0.39296	-0.54390	-0.28135	0.55174	-0.58152
70403	0.32427	0.35108	-0.13747	0.15691	0.34472	0.02193
70422	0.34274	-0.20720	0.22692	-0.23345	0.14245	-0.04147
70441	1.11225	-0.41513	0.42388	-0.21250	0.26390	-0.08553
70443	0.33829	-0.66766	0.06593	-0.24221	0.28241	0.40017
70444	0.47821	-0.54158	0.65863	-0.21725	0.39110	0.02668
70449	-0.54458	-0.61942	0.89775	-0.01638	-0.25919	0.71503
70453	0.22215	-1.13396	-1.36611	-0.12814	0.88025	-0.11373
70462	-0.25142	-0.56381	0.69698	-0.03851	-0.19655	0.09865
70466	0.02468	-0.64591	-0.13104	-0.10075	0.21023	0.71354
70706	-1.03456	-0.76597	-1.06423	0.10162	0.45737	-0.49792
70710	-0.45461	-0.45857	-0.95263	-0.30713	0.49751	-0.09237
70711	-0.13319	-0.66580	-0.09410	-0.00094	0.17389	0.58361
70712	0.68070	-0.44870	-2.23726	-0.60796	-7.42860	-0.18245
70714	-0.23834	0.39461	-0.55229	-0.30622	0.43640	-0.56677
70715	1.57174	-0.67143	1.10715	-0.31288	1.01611	0.57712
70717	-0.46834	-0.88615	0.62035	1.34992	-0.92624	-1.31602
70719	-0.39257	0.23746	-0.25171	-0.27288	-0.02381	-0.06575
70720	-0.80691	-0.87799	-0.39086	0.30390	0.29302	-0.51709
70721	1.05392	0.28351	0.33965	-1.26358	-0.69740	2.16847
70722	0.27221	-0.27021	0.15440	-0.11044	0.17174	-0.19466
70725	0.72605	-0.10376	-0.71395	-1.16367	0.17730	-0.89587
70726	-0.73964	-0.44618	-0.40355	0.09079	0.36250	0.12671
70729	1.56242	-1.36620	0.48145	-1.09474	-0.38192	1.85867
70730	-0.25741	-0.40677	0.09146	-0.47341	-0.08681	-0.41606
70732	-0.32496	-0.45139	1.02722	-0.12374	-0.50465	-0.29020
70733	-0.63366	-0.93957	0.62060	0.08602	-0.04566	0.11613
70734	-0.32757	-0.82015	-1.52202	-0.31385	1.01450	-0.24685
70736	0.32215	-0.68452	0.54560	0.00344	0.37381	-0.74005
70737	-0.74324	0.07332	-0.59551	0.21862	0.26780	0.57183
70739	-1.45067	-0.15698	-0.33696	0.27635	0.27250	-0.51296
70740	-0.06795	-0.87858	0.45019	-0.15289	0.32790	0.06348
70744	-0.54648	-1.09691	-0.20799	-0.08259	-0.00669	-0.12271
70747	-0.57819	1.34085	3.84521	-0.59665	-1.63548	-0.64985
70748	0.50856	-0.09874	-0.39325	0.14813	-1.31566	-0.73271
70749	-0.74289	-0.48355	1.33869	0.15509	-0.12993	0.34591
70752	-0.42397	-0.23720	1.30146	0.11127	-0.43826	0.86552

Table cont.

70753	1.56005	-0.67444	0.37238	0.00170	0.82032	-0.45924
70754	-0.51649	-1.10569	-0.20726	0.07522	0.20733	0.10627
70755	-0.48274	-0.74332	-0.03561	0.20305	0.28420	-0.45315
70756	-0.72170	-0.26923	0.26715	-0.64683	-0.14268	-0.49012
70757	1.08195	-0.13788	-0.24698	-0.38415	0.65429	-0.72105
70759	0.19057	-0.11672	1.19413	-0.15605	0.03581	-0.01821
70760	1.05222	0.66133	0.54231	-0.30526	0.27121	-0.21652
70761	1.00727	-0.43293	0.43104	-0.42391	0.23854	-0.03729
70762	-1.76887	-0.31333	0.78267	0.77565	-0.50151	-0.75029
70764	0.31266	-0.00362	0.13828	-0.22405	0.19774	-0.22692
70767	0.03702	-0.11039	-0.28047	-0.26219	0.11514	-0.10467
70769	-1.38953	-0.40135	-1.09835	0.38942	0.59500	-0.20825
70770	-1.51364	-0.62708	-0.25803	0.13480	0.29095	-0.34781
70772	0.27307	-0.11382	0.19641	-0.50712	0.08967	-0.41779
70773	0.36920	-0.36130	2.03792	0.93902	-0.34853	-0.31689
70774	-0.95186	-0.84001	-0.52755	0.09777	0.26766	-0.40164
70775	-0.21776	-0.21494	-0.05494	-0.21119	0.10819	-0.27262
70776	0.30596	0.04352	-1.11295	-0.30034	-2.44586	-1.01092
70777	-0.69013	-0.82807	-0.25522	-0.15642	0.23735	-0.22567
70778	-0.24062	-0.71092	-0.29395	0.05006	0.33525	0.01931
70780	0.44483	-0.42099	-0.59851	-0.88248	0.64707	-0.36884
70781	-0.22190	-0.68938	0.70017	-0.40217	-1.53088	0.47866
70782	0.33484	-1.70917	0.10399	-0.71446	0.37224	6.46227
70783	-1.01977	-0.10755	1.14299	0.42568	-0.32829	-0.31926
70785	-0.71704	-0.91185	-0.81749	0.15293	0.53560	-0.08572
70787	3.28977	-0.17640	3.34480	2.17190	-0.21013	-2.05255
70788	0.98175	-0.01170	-0.00941	-0.47761	0.19765	-0.34149
70789	1.51977	-0.24764	-0.94175	-1.01205	0.29296	-0.20774
70791	-0.78243	-0.06016	-0.16944	-0.17078	0.10057	-0.45690
70801	1.75525	-0.40789	-1.64882	7.60011	-0.02872	1.15067
70802	1.98513	2.83681	-0.28962	-0.61366	0.18203	1.00824
70805	1.78621	1.81067	-1.37892	-0.69581	0.77888	-0.72757
70806	0.35379	2.27425	0.52759	0.59489	0.47237	0.07995
70807	2.10127	0.98158	-1.53480	-0.69877	0.50860	-0.91272
70808	-1.23436	2.65373	0.43955	0.55479	-0.36562	0.85027
70809	-1.50537	1.99276	1.02199	0.65283	-0.06955	0.61744
70810	-1.54128	1.57663	-0.72083	0.43740	0.12498	-0.06463
70811	0.34223	0.90471	-0.39509	-0.66395	0.37375	-0.79365
70812	1.22343	1.01505	-1.85174	-0.80558	0.90559	-1.19901
70814	-0.30386	1.64877	-0.20784	-0.32498	0.44146	0.05407
70815	-0.69286	2.82693	1.48589	-0.34755	-0.02101	0.66696
70816	-0.98887	1.96366	-0.44416	0.62306	0.07732	0.68147
70817	-2.21573	0.72818	-0.91778	0.46344	0.37791	-0.95237
70818	-1.15248	0.17283	-0.26568	0.06272	0.35739	-0.35674
70819	-0.90140	1.02303	0.57590	-0.25155	0.39973	0.69636
70820	0.12790	2.56951	-1.74067	0.88452	-0.73423	2.25538

Appendix F. Directional Analysis for Each Component

Table F.1: Component 1: Poverty.

Dominant Variables	Loading	Proportionality to Vulnerability
PCTPOVER	0.866	+
PCTBLACK	0.832	+
PCTNOHIGH	0.701	+
PCTUNEMPL	0.683	+
PCTFEMHH	0.662	+
PCTLABOR	-0.586	-
MEDRENT	-0.609	-
PCTHH75	-0.756	-
PCINCOME	-0.808	-
Component Directionality	+	

Table F.2: Component 2: Urbanization.

Dominant Variables	Loading	Proportionality to Vulnerability
HOUSESQM	0.858	+
PCTASIAN	0.811	+
PCTURBAN	0.685	+
PCTRENTER	0.581	+
PCTMOBILE	-0.839	+
Component Directionality	||	

Table F.3: Component 3: Elderly.

Dominant Variables	Loading	Proportionality to Vulnerability
PCTOLD	0.830	+
MEDAGE	0.697	+
PCTHHSS	0.629	+
PCTFEMLAB	-0.592	-
Component Directionality	+	

Table F.4: Component 4: Affluence.

Dominant Variables	Loading	Proportionality to Vulnerability
PCHEALTH	0.837	-
MEDHOUSVAL	0.687	-
AVEHHSIZE	-0.682	+
Component Directionality	-	

Table F.5: Component 5: Female and children.

Dominant Variables	Loading	Proportionality to Vulnerability
PCTFEM	0.896	+
PCTKID	0.804	+
PCTLABOR	0.606	-
Component Directionality	||	

Table F.6: Component 6: Race and ethnicity.

Dominant Variables	Loading	Proportionality to Vulnerability
PCTINDIAN	0.788	+
PCTFOREIGN	0.645	+
PCTHISPA	0.579	+
Component Directionality	+	

Appendix G. Social Vulnerability Index Scores

Table G.1: Social vulnerability index scores.

Zip Code	Parish	Index Score	Standardized Index Score
70801	East Baton Rouge	-5.91	-3.07
70817	East Baton Rouge	-3.44	-2.01
70739	East Baton Rouge	-2.15	-1.46
70769	Ascension	-2.09	-1.43
70762	Pointe Coupee	-1.70	-1.26
70706	Livingston	-1.47	-1.17
70770	East Baton Rouge	-1.34	-1.11
70818	East Baton Rouge	-1.31	-1.10
70791	East Baton Rouge	-1.08	-1.00
70810	East Baton Rouge	-1.06	-0.99
70774	Ascension	-0.87	-0.91
70720	West Baton Rouge	-0.85	-0.90
70717	Pointe Coupee	-0.70	-0.84
70737	Ascension	-0.64	-0.81
70785	Livingston	-0.33	-0.67
70726	Livingston	-0.30	-0.66
70710	West Baton Rouge	-0.24	-0.64
70714	East Baton Rouge	-0.22	-0.63
70783	Pointe Coupee	-0.19	-0.61
70719	West Baton Rouge	-0.18	-0.61
70755	Pointe Coupee	-0.15	-0.60
70775	East Baton Rouge, East Feliciana, West Feliciana	-0.01	-0.54
70777	East Feliciana	0.05	-0.51
70734	Ascension	0.05	-0.51
70756	Pointe Coupee	0.11	-0.49
70767	West Baton Rouge	0.14	-0.47
70744	Livingston	0.31	-0.40
70730	East Feliciana	0.38	-0.37
70778	Ascension	0.48	-0.33
70725	Ascension	0.56	-0.29
70754	Livingston	0.62	-0.27
70748	East Baton Rouge, East Feliciana, West Feliciana	0.65	-0.26
70764	Iberville	0.65	-0.25
70816	East Baton Rouge	0.67	-0.25
70403	Livingston, Tangipahoa	0.75	-0.21
70772	Iberville	0.76	-0.21

Table cont.

70722	East Feliciana	0.78	-0.20
70453	St. Helena	0.88	-0.15
70812	East Baton Rouge	0.90	-0.15
70776	Iberville	0.97	-0.12
70733	Livingston	1.00	-0.10
70346	Ascension	1.06	-0.08
70811	East Baton Rouge	1.10	-0.06
70422	St. Helena, Tangipahoa	1.11	-0.06
70736	Pointe Coupee, West Baton Rouge	1.18	-0.03
70711	Livingston	1.20	-0.02
70757	Iberville	1.29	0.02
70788	Iberville	1.32	0.03
70462	Livingston	1.34	0.04
70749	Pointe Coupee	1.40	0.07
70780	Iberville	1.43	0.08
70732	Pointe Coupee	1.49	0.11
70809	East Baton Rouge	1.54	0.13
70466	Livingston, St. Helena, Tangipahoa	1.56	0.14
70759	Pointe Coupee	1.68	0.19
70740	Iberville	1.81	0.24
70807	East Baton Rouge	1.84	0.26
70773	Pointe Coupee	1.86	0.27
70789	East Feliciana	1.92	0.29
70814	East Baton Rouge	1.96	0.31
70449	Livingston	1.96	0.31
70443	Livingston, St. Helena, Tangipahoa	2.00	0.32
70819	East Baton Rouge	2.05	0.35
70752	Pointe Coupee	2.31	0.46
70444	St. Helena	2.31	0.46
70441	St. Helena	2.34	0.47
70761	East Feliciana	2.50	0.54
70808	East Baton Rouge	2.52	0.55
70760	Pointe Coupee	2.62	0.59
70787	West Feliciana	2.80	0.67
70805	East Baton Rouge	2.97	0.74
70753	Pointe Coupee	2.97	0.74
70820	East Baton Rouge	3.06	0.78
70806	East Baton Rouge	3.11	0.80
70781	Pointe Coupee	3.58	1.00
70815	East Baton Rouge	4.66	1.47
70715	Pointe Coupee	5.26	1.73
70721	Iberville	5.81	1.96
70747	Pointe Coupee	6.19	2.13
70802	East Baton Rouge	6.34	2.19
70729	West Baton Rouge	6.75	2.37
70712	West Feliciana	6.75	2.37
70782	West Feliciana	9.70	3.64

Vita

María Belén Toscano is a Louisiana State University chemical engineer. A native from Quito, Ecuador, she moved to the United States where she earned an associate of arts degree in chemical engineering at Miami Dade College in 2004. She later completed her bachelor's degree at LSU in 2009 with minors in biological sciences and international studies. The same year she began her post-graduate studies at LSU to pursue a master's degree in environmental sciences with a minor in statistics. Her research interests include environmental management and policy, international affairs, and community development.