

# Social Vulnerability to Environmental Hazards\*

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*Objective.* County-level socioeconomic and demographic data were used to construct an index of social vulnerability to environmental hazards, called the Social Vulnerability Index (SoVI) for the United States based on 1990 data. *Methods.* Using a factor analytic approach, 42 variables were reduced to 11 independent factors that accounted for about 76 percent of the variance. These factors were placed in an additive model to compute a summary score—the Social Vulnerability Index. *Results.* There are some distinct spatial patterns in the SoVI, with the most vulnerable counties clustered in metropolitan counties in the east, south Texas, and the Mississippi Delta region. *Conclusion.* Those factors that contribute to the overall score often are different for each county, underscoring the interactive nature of social vulnerability—some components increase vulnerability; others moderate the effects.

Generally speaking, vulnerability to environmental hazards means the potential for loss. Since losses vary geographically, over time, and among different social groups, vulnerability also varies over time and space. Within the hazards literature, vulnerability has many different connotations, depending on the research orientation and perspective (Dow, 1992; Cutter, 1996, 2001a). There are three main tenets in vulnerability research: the identification of conditions that make people or places vulnerable to extreme natural events, an exposure model (Burton, Kates, and White, 1993; Anderson, 2000); the assumption that vulnerability is a social condition, a measure of societal resistance or resilience to hazards (Blaikie et al., 1994;

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Hewitt, 1997); and the integration of potential exposures and societal resilience with a specific focus on particular places or regions (Kasperson, Kasperson, and Turner, 1995; Cutter, Mitchell, and Scott, 2000).

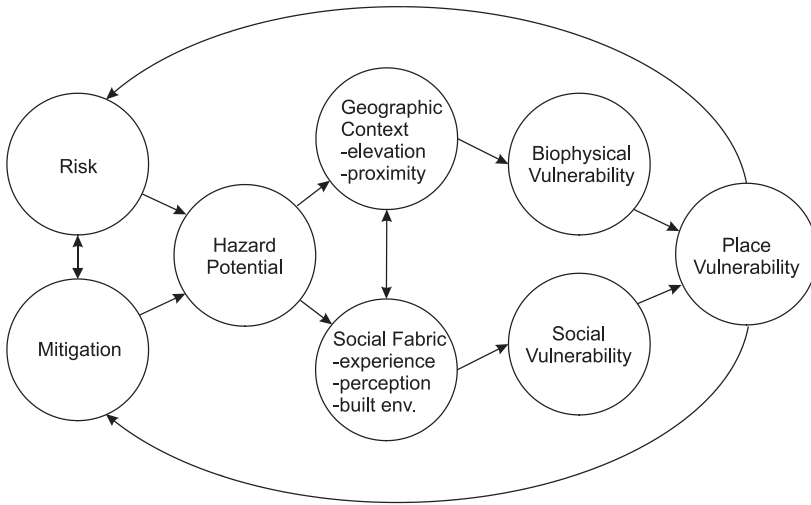
### **The Vulnerability Paradox**

Although considerable research attention has examined components of biophysical vulnerability and the vulnerability of the built environment (Mileti, 1999), we currently know the least about the social aspects of vulnerability. Socially created vulnerabilities are largely ignored, mainly due to the difficulty in quantifying them, which also explains why social losses are normally absent in after-disaster cost/loss estimation reports. Instead, social vulnerability is most often described using the individual characteristics of people (age, race, health, income, type of dwelling unit, employment). Social vulnerability is partially the product of social inequalities—those social factors that influence or shape the susceptibility of various groups to harm and that also govern their ability to respond. However, it also includes place inequalities—those characteristics of communities and the built environment, such as the level of urbanization, growth rates, and economic vitality, that contribute to the social vulnerability of places. To date, there has been little research effort focused on comparing the social vulnerability of one place to another. For example, is there a robust and consistent set of indicators for assessing social vulnerability that facilitates comparisons among diverse places, such as eastern North Carolina and southern California? How well do these indicators differentiate places based on the level of social vulnerability and how well do these factors explain differences in economic losses from natural hazards? This article examines these questions through a comparative analysis of social vulnerability to natural hazards among U.S. counties.

This article utilizes the hazards-of-place model of vulnerability (Cutter, 1996; Cutter, Mitchell, and Scott, 2000; Heinz Center for Science, Economics, and the Environment, 2002) to examine the components of social vulnerability. In this conceptualization (Figure 1), risk (an objective measure of the likelihood of a hazard event) interacts with mitigation (measures to lessen risks or reduce their impact) to produce the hazard potential. The hazard potential is either moderated or enhanced by a geographic filter (site and situation of the place, proximity) as well as the social fabric of the place. The social fabric includes community experience with hazards, and community ability to respond to, cope with, recover from, and adapt to hazards, which in turn are influenced by economic, demographic, and housing characteristics. The social and biophysical vulnerabilities interact to produce the overall place vulnerability. In this article we examine only the social vulnerability portion of the conceptual model.

FIGURE 1

The Hazards-of-Place Model of Vulnerability (Modified from Cutter, 1996)



**Redirecting Social Indicators Research**

In the 1960s and 1970s, social indicators research was a thriving topic within the social sciences with volumes written on theoretical and methodological issues (Duncan, 1969, 1984; Land, 1983; Land and Spilerman, 1975; Smith, 1973; Smith, 1981), and applications to social policy formation (Rossi and Gilmartin, 1980). The development of environmental indicators followed shortly thereafter, with quality-of-life studies emerging as an amalgam of the two (Cutter, 1985).

As a current research endeavor, social indicators and quality-of-life studies have lost some of their original luster, although specialized journals (e.g., *Social Indicators Research*) remain as outlets for focused empirical research on the topic. Much of the contemporary work on social and quality-of-life indicators is relegated to popular rating places guides such as *The Places Rated Almanac* (Savageau, 2000), *America's Top-Rated Cities* (Garoogian, 1999), or comparative rankings of environmental quality (*Green Metro Index* by World Resources Institute, 1993; *Green Index* by Hall and Kerr, 1991). Also, there are a few examples of comparative measures of community health at the county level (Miringhoff, 1999; Shaw-Taylor, 1999; U.S. Health and Human Services Administration, 2001). One of the best national assessments that integrates demographic, public health, and environmental quality indicators is now more than a decade old, however (Goldman, 1991).

Social and environmental indicators research is experiencing a renaissance at present, especially in the arena of sustainability science. For example, the United Nations Development Program's Human Development Index (UNDP, 2000) provides a composite indicator of human well-being, as well as indicators of gender disparity and poverty among nations—measures that have been used for more than a decade. Similarly, the World Bank (2001) provides data on the links between environmental conditions and human welfare, especially in developing nations, to monitor national progress toward a more sustainable future. An index has been developed to measure the environmental sustainability of national economies (World Economic Forum, 2000, 2002; Esty and Cornelius, 2002). Meanwhile, a set of indicators to monitor and assess ecological conditions for public policy decisions has been proposed (National Research Council, 2000). Similarly, the U.S. Environmental Protection Agency (2002) is using a small set of environmental indicators to track progress in hazardous waste remediation. Finally, the social capital embodied in various communities has been surveyed in selected communities to determine a baseline and comparative assessment of American social and civic engagement at the local level (Social Capital Community Benchmark Survey, 2002). Despite these efforts, there still is no consistent set of metrics used to assess vulnerability to environmental hazards, although there have been calls for just such an index (Comfort et al., 1999; Cutter, 2001b).

### **Factors Influencing Social Vulnerability**

There is a general consensus within the social science community about some of the major factors that influence social vulnerability. These include: 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; building stock and age; frail and physically limited individuals; and type and density of infrastructure and lifelines (Cutter, 2001a; Tierney, Lindell, and Perry, 2001; Putnam, 2000; Blaikie et al., 1994). Disagreements arise in the selection of specific variables to represent these broader concepts.

Those characteristics that influence social vulnerability most often found in the literature are listed in Table 1, along with the relevant research that identified them. Among the generally accepted are age, gender, race, and socioeconomic status. Other characteristics identify special needs populations or those that lack the normal social safety nets necessary in disaster recovery, such as the physically or mentally challenged, non-English-speaking immigrants, the homeless, transients, and seasonal tourists. The quality of human settlements (housing type and construction, infrastructure, and lifelines) and the built environment are also important in understanding social vulnerability, especially as these characteristics influence potential

TABLE 1  
Social Vulnerability Concepts and Metrics

Concept	Description	Increases (+) or Decreases (-) Social Vulnerability
Socioeconomic status (income, political power, prestige)	The ability to absorb losses and enhance resilience to hazard impacts. Wealth enables communities to absorb and recover from losses more quickly due to insurance, social safety nets, and entitlement programs. <i>Sources:</i> Cutter, Mitchell, and Scott (2000), Burton, Kates, and White (1993), Blaikie et al. (1994), Peacock, Morrow, and Gladwin (1997, 2000), Hewitt (1997), Puente (1999), and Platt (1999).	High status (+/-) Low income or status (+)
Gender	Women can have a more difficult time during recovery than men, often due to sector-specific employment, lower wages, and family care responsibilities. <i>Sources:</i> Blaikie et al. (1994), Enarson and Morrow (1998), Enarson and Scanlon (1999), Morrow and Phillips (1999), Fothergill (1996), Peacock, Morrow, and Gladwin (1997, 2000), Hewitt (1997), and Cutter (1996).	Gender (+)
Race and ethnicity	Imposes language and cultural barriers that affect access to post-disaster funding and residential locations in high hazard areas. <i>Sources:</i> Pulido (2000), Peacock, Morrow, and Gladwin (1997, 2000), Bolin with Stanford (1998), and Bolin (1993).	Nonwhite (+) Non-Anglo (+)
Age	Extremes of the age spectrum affect the movement out of harm's way. Parents lose time and money caring for children when daycare facilities are affected; elderly may have mobility constraints or mobility concerns increasing the burden of care and lack of resilience. <i>Sources:</i> Cutter, Mitchell, and Scott (2000), O'Brien and Mileti (1992), Hewitt (1997), and Ngo (2001).	Elderly (+) Children (+)
Commercial and industrial development	The value, quality, and density of commercial and industrial buildings provides an indicator of the state of economic health of a community, and potential losses in the business community, and longer-term issues with recovery after an event.	High density (+) High value (+/-)

TABLE 1 — Continued

Employment loss	<p><b>Sources:</b> Heinz Center for Science, Economics, and the Environment (2000) and Webb, Tierney, and Dahlhamer (2000).</p> <p>The potential loss of employment following a disaster exacerbates the number of unemployed workers in a community, contributing to a slower recovery from the disaster.</p>	Employment loss (+)
Rural/urban	<p><b>Source:</b> Mileti (1999).</p> <p>Rural residents may be more vulnerable due to lower incomes and more dependent on locally based resource extraction economies (e.g., farming, fishing). High-density areas (urban) complicate evacuation out of harm's way.</p> <p><b>Source:</b> Cutter, Mitchell, and Scott (2000), Cova and Church (1997), and Mitchell (1999).</p>	Rural (+) Urban (+)
Residential property	<p>The value, quality, and density of residential construction affects potential losses and recovery. Expensive homes on the coast are costly to replace; mobile homes are easily destroyed and less resilient to hazards.</p> <p><b>Source:</b> Heinz Center for Science, Economics, and the Environment (2000), Cutter, Mitchell, and Scott (2000), and Bolin and Stanford (1991).</p>	Mobile homes (+)
Infrastructure and lifelines	<p>Loss of sewers, bridges, water, communications, and transportation infrastructure compounds potential disaster losses. The loss of infrastructure may place an insurmountable financial burden on smaller communities that lack the financial resources to rebuild.</p> <p><b>Source:</b> Heinz Center for Science, Economics, and the Environment (2000) and Platt (1995).</p>	Extensive infrastructure (+)
Renters	<p>People that rent do so because they are either transient or do not have the financial resources for home ownership. They often lack access to information about financial aid during recovery. In the most extreme cases, renters lack sufficient shelter options when lodging becomes uninhabitable or too costly to afford.</p> <p><b>Source:</b> Heinz Center for Science, Economics, and the Environment (2000) and Morrow (1999).</p>	Renters (+)

TABLE 1 — Continued

Occupation	<p>Some occupations, especially those involving resource extraction, may be severely impacted by a hazard event. Self-employed fisherman suffer when their means of production is lost and may not have the requisite capital to resume work in a timely fashion and thus will seek alternative employment. Those migrant workers engaged in agriculture and low-skilled service jobs (housekeeping, childcare, and gardening) may similarly suffer, as disposable income fades and the need for services declines. Immigration status also affects occupational recovery.</p> <p><b>Source:</b> Heinz Center for Science, Economics, and the Environment (2000), Hewitt (1997), and Puente (1999).</p>	<p>Professional or managerial (–)  Clerical or laborer (+)  Service sector (+)</p>
Family structure	<p>Families with large numbers of dependents or single-parent households often have limited finances to outsource care for dependents, and thus must juggle work responsibilities and care for family members. All affect the resilience to and recovery from hazards.</p> <p><b>Source:</b> Blaikie et al. (1994), Morrow (1999), Heinz Center for Science, Economics, and the Environment (2000), and Puente (1999).</p>	<p>High birth rates (+)  Large families (+)  Single-parent households (+)</p>
Education	<p>Education is linked to socioeconomic status, with higher educational attainment resulting in greater lifetime earnings. Lower education constrains the ability to understand warning information and access to recovery information.</p> <p><b>Source:</b> Heinz Center for Science, Economics, and the Environment (2000).</p>	<p>Little education (+)  Highly educated (–)</p>
Population growth	<p>Counties experiencing rapid growth lack available quality housing, and the social services network may not have had time to adjust to increased populations. New migrants may not speak the language and not be familiar with bureaucracies for obtaining relief or recovery information, all of which increase vulnerability.</p> <p><b>Source:</b> Heinz Center for Science, Economics, and the Environment (2000), Cutter, Mitchell, and Scott (2000), Morrow (1999), and Puente (1999).</p>	<p>Rapid growth (+)</p>
Medical services	<p>Health care providers, including physicians, nursing homes, and hospitals, are important post-event</p>	<p>Higher density of medical (–)</p>

**TABLE 1 — Continued**

	sources of relief. The lack of proximate medical services will lengthen immediate relief and longer-term recovery from disasters.	
	<i>Source:</i> Heinz Center for Science, Economics, and the Environment (2000), Morrow (1999), and Hewitt (1997).	
Social dependence	Those people who are totally dependent on social services for survival are already economically and socially marginalized and require additional support in the post-disaster period.	High dependence (+) Low dependence (-)
	<i>Source:</i> Morrow (1999), Heinz Center for Science, Economics, and the Environment (2000), Drabek (1996), and Hewitt (2000).	
Special needs populations	Special needs populations (infirm, institutionalized, transient, homeless), while difficult to identify and measure, are disproportionately affected during disasters and, because of their invisibility in communities, mostly ignored during recovery.	Large special needs population (+)
	<i>Source:</i> Morrow (1999) and Tobin and Ollenburger (1993).	

SOURCE: Cutter, Boruff, and Shirley (2001); Heinz Center for Science, Economics, and the Environment (2002).

economic losses, injuries, and fatalities from natural hazards. Given their general acceptance in the literature, can we empirically define a robust set of variables that capture these characteristics, which then allows us to monitor changes in social vulnerability geographically and over time?

**Methods**

To examine the social vulnerability, socioeconomic data were collected for 1990 for all 3,141 U.S. counties, our unit of analysis. Using the U.S. Census (City and County Data Books for 1994 and 1998), specific variables were collected that characterized the broader dimensions of social vulnerability identified in Table 1. Originally, more than 250 variables were collected, but after testing for multicollinearity among the variables, a subset of 85 raw and computed variables was derived. After all the computations and normalization of data (to percentages, per capita, or density functions), 42 independent variables were used in the statistical analyses (Table 2). The primary statistical procedure used to reduce the data was factor analysis,



TABLE 2  
Variable Names and Descriptions

Name	Description
MED_AGE90	Median age, 1990
PERCAP89	Per capita income (in dollars), 1989
MVALOO90	Median dollar value of owner-occupied housing, 1990
MEDRENT90	Median rent (in dollars) for renter-occupied housing units, 1990
PHYSICN90	Number of physicians per 100,000 population, 1990
PCTVOTE92	Vote cast for president, 1992—percent voting for leading party (Democratic)
BRATE90	Birth rate (number of births per 1,000 population), 1990
MIGRA_97	Net international migration, 1990–1997
PCTFARMS92	Land in farms as a percent of total land, 1992
PCTBLACK90	Percent African American, 1990
PCTINDIAN90	Percent Native American, 1990
PCTASIAN_90	Percent Asian, 1990
PCTHISPANIC90	Percent Hispanic, 1990
PCTKIDS90	Percent of population under five years old, 1990
PCTOLD90	Percent of population over 65 years, 1990
PCTVLUN91	Percent of civilian labor force unemployed, 1991
AVGPERHH	Average number of people per household, 1990
PCTHH7589	Percent of households earning more than \$75,000, 1989
PCTPOV90	Percent living in poverty, 1990
PCTRENT90	Percent renter-occupied housing units, 1990
PCTRFARM90	Percent rural farm population, 1990
DEBREV92	General local government debt to revenue ratio, 1992
PCTMOBL90	Percent of housing units that are mobile homes, 1990
PCTNOHS90	Percent of population 25 years or older with no high school diploma, 1990
HODENUT90	Number of housing units per square mile, 1990
HUPTDEN90	Number of housing permits per new residential construction per square mile, 1990
MAESDEN92	Number of manufacturing establishments per square mile, 1992
EARNDEN90	Earnings (in \$1,000) in all industries per square mile, 1990
COMDEV92	Number of commercial establishments per square mile, 1990
RPROP92	Value of all property and farm products sold per square mile, 1990
CVBRPC91	Percent of the population participating in the labor force, 1990
FEMLBR90	Percent females participating in civilian labor force, 1990
AGRIPC90	Percent employed in primary extractive industries (farming, fishing, mining, and forestry), 1990
TRANPC90	Percent employed in transportation, communications, and other public utilities, 1990
SERVPC90	Percent employed in service occupations, 1990
NRRESPC91	Per capita residents in nursing homes, 1991
HOSP91	Per capita number of community hospitals, 1991
PCCHGPOP90	Percent population change, 1980/1990
PCTURB90	Percent urban population, 1990
PCTFEM90	Percent females, 1990
PCTF_HH90	Percent female-headed households, no spouse present, 1990
SSBENPC90	Per capita Social Security recipients, 1990

specifically, principal components analysis.<sup>1</sup> The use of a reductionist technique such as factor analysis allows for a robust and consistent set of variables that can be monitored over time to assess any changes in overall vulnerability. The technique also facilitates replication of the variables at other spatial scales, thus making data compilation more efficient. A total of 11 factors was produced, which explained 76.4 percent of the variance among all counties.<sup>2</sup>

### **Empirically Defining the Underlying Dimensions of Social Vulnerability**

Eleven composite factors were found that differentiated U.S. counties according to their relative level of social vulnerability in 1990 (Table 3). Each of these is briefly described below.

#### ***Personal Wealth***

The first factor identified the individual personal wealth of counties as measured by per capita income, percentage of households earning more than \$75,000 per year, median house values, and median rents. The wealth variables loaded positively on this factor and the lack of wealth (poverty) variables, negatively. The wealth factor explains 12.4 percent of the variance. Wealth enables communities to quickly absorb and recover from losses, but it also means that there may be more material goods at risk in the first place. On the other hand, there is more agreement that lack of wealth is a primary contributor to social vulnerability as fewer individual and community resources for recovery are available, thereby making the community less resilient to the hazard impacts.

#### ***Age***

The two demographic groups most affected by disasters, children and the elderly, are identified in the second factor, which explains 11.9 percent of the variation among counties, an empirical finding also consistent with the literature. The preponderance of children in the community

<sup>1</sup>This procedure cannot be performed with missing values, so in these cases a value of zero was substituted. We recognize that assigning a value of zero for a missing variable for a case may not accurately represent the true vulnerability based on that one variable, and that in all likelihood it would underestimate the level of vulnerability for those affected counties. From our perspective, it was more important to include all U.S. counties in the analysis (a spatial decision), rather than dropping them (the majority of which were in Alaska and Hawaii).

<sup>2</sup>To simplify the structure of underlying dimensions and produce more independence among the factors, a varimax rotation was used in the factor analysis. The varimax rotation minimizes the number of variables that load high on a single factor, thereby increasing the percentage variation between each factor. Eigenvalues greater than 1.00 were used to generate the 11 factors and were based on a scree diagram showing a distinct break in the values.

**TABLE 3**  
**Dimensions of Social Vulnerability**

Factor	Name	Percent Variation Explained	Dominant Variable	Correlation
1	Personal wealth	12.4	Per capita income	+0.87
2	Age	11.9	Median age	-0.90
3	Density of the built environment	11.2	No. commercial establishments/mi <sup>2</sup>	+0.98
4	Single-sector economic dependence	8.6	% employed in extractive industries	+0.80
5	Housing stock and tenancy	7.0	% housing units that are mobile homes	-0.75
6	Race—African American	6.9	% African American	+0.80
7	Ethnicity—Hispanic	4.2	% Hispanic	+0.89
8	Ethnicity—Native American	4.1	% Native American	+0.75
9	Race—Asian	3.9	% Asian	+0.71
10	Occupation	3.2	% employed in service occupations	+0.76
11	Infrastructure dependence	2.9	% employed in transportation, communication, and public utilities	+0.77

and high birth rates both load positively on this dimension. Median age, on the other hand, loads negatively. The other demographic group, the elderly, is measured by the percentage of the population over 65 and percentage receiving Social Security benefits. These variables load negatively on this dimension.

***Density of the Built Environment***

The third factor also confirms findings in the literature, and describes the degree of development of the built environment. As measured by the density of manufacturing and commercial establishments, housing units, and new housing permits, this factor highlights those counties where significant structural losses might be expected from a hazard event. Eleven percent of the variation in counties is captured by this factor.

### ***Single-Sector Economic Dependence***

A singular reliance on one economic sector for income generation creates a form of economic vulnerability for counties. The boom and bust economies of oil development, fishing, or tourism-based coastal areas are good examples—in the heyday of prosperity, income levels are high, but when the industry sees hard times or is affected by a natural hazard, the recovery may take longer. The agricultural sector is no exception and is, perhaps, even more vulnerable given its dependence on climate. Any change in weather conditions or increases in hydrometeorological hazards, such as flooding, drought, or hail, can affect annual and decadal incomes and the sustainability of the resource base. This fourth factor explains 8.6 percent of the variation, with percentage rural farm population and percent employment in extractive industries having the highest correlations.

### ***Housing Stock and Tenancy***

The quality and ownership of housing is an important component of vulnerability. The fifth factor explains 7 percent of the variance, with the most dominant variables including mobile homes, renters, and urban living. The nature of the housing stock (mobile homes) and the nature of ownership (renters) and the location (urban) combine to produce the social vulnerability depicted in this factor. The displacement of affected populations from damaged dwellings is potentially greater in urban areas than rural ones, while the destruction of mobile homes is potentially greater in rural areas (where they are often the dominant form of housing).

### ***Race***

Race contributes to social vulnerability through the lack of access to resources, cultural differences, and the social, economic, and political marginalization that is often associated with racial disparities. Our sixth factor identifies race, specifically African American, as an indicator of social vulnerability. This factor also correlates highly with percentage female-headed households, noting that counties with high percentages of African-American female-headed households are among the most vulnerable. This factor explains 6.9 percent of the variation among U.S. counties. Factor 9 identifies another racial group, Asians, and accounts for 3.9 percent of the variability among counties.

### ***Ethnicity***

Like race, ethnicity also is a clearly defined factor contributing to vulnerability and this factor is mostly correlated with Hispanic in Factor 7

and Native American in Factor 8. These factors explain 4.2 percent and 4.1 percent of the variation among U.S. counties, respectively.

### ***Occupation***

The literature suggests that occupation is an important dimension of vulnerability. The 10th factor, in fact, distinguishes counties based on occupations—primarily lower wage service occupations such as personal services. As might be expected, counties heavily dependent on this employment base might suffer greater impacts from natural hazards and face slower recovery from disasters. This factor explains 3.2 percent of the variance among counties.

### ***Infrastructure Dependence***

The 11th factor (explaining 2.9 percent of the variance) is a hybrid one that loads highly on two individual indicators—large debt to revenue ratio and percent employed in public utilities and other infrastructure (transportation and communications). The economic vitality and revenue-generating capability of a county is a good indicator of its ability to divert resources to hazard mitigation and, ultimately, recovery should the disaster occur. Those counties with high debt to revenue ratio and primary dependence on infrastructure employment have fewer localized resources for recovery, thereby affecting their ability to successfully recover from a disaster.

### **The Social Vulnerability Index (SoVI)**

The factor scores were added to the original county file as 11 additional variables and then placed in an additive model to produce the composite social vulnerability index score (SoVI) for each county. The SoVI is a relative measure of the overall social vulnerability for each county. We selected an additive model, thereby making no *a priori* assumption about the importance of each factor in the overall sum. In this way, each factor was viewed as having an equal contribution to the county's overall vulnerability. In the absence of a defensible method for assigning weights, we felt this was the best option. Further, all factors were scaled so that positive values indicated higher levels of vulnerability; negative values decreased or lessened the overall vulnerability. In those instances where the effect was ambiguous (both increased and decreased vulnerability), we used the absolute value. To determine the most and least vulnerable of the counties (e.g., the outliers based on a normal curve), the SoVI scores were mapped based on standard deviations from the mean into five categories ranging from -1 on the lower end to +1 on the upper end.

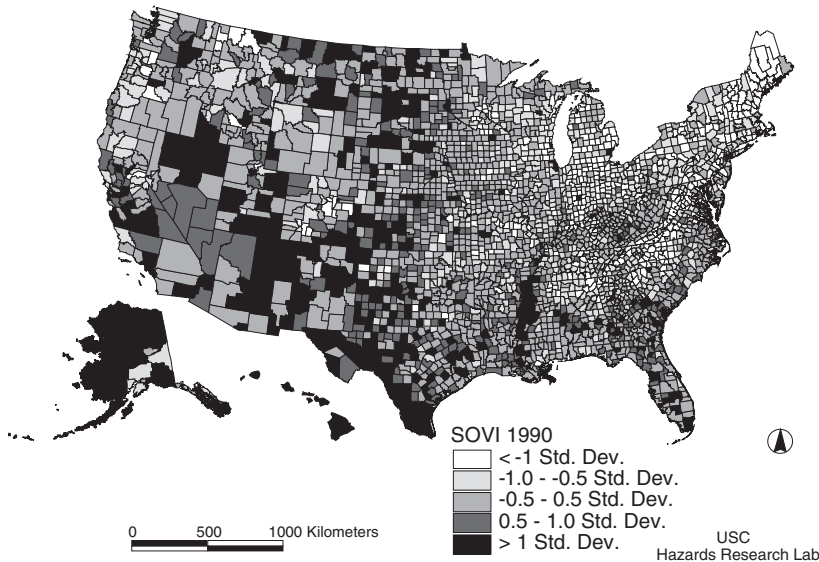
**The Geography of Social Vulnerability**

As expected, the vast majority of U.S. counties exhibit moderate levels of social vulnerability. The SoVI ranges from  $-9.6$  (low social vulnerability) to  $49.51$  (high social vulnerability) with mean vulnerability score of  $1.54$  ( $SD = 3.38$ ) for all U.S. counties. With some notable exceptions, the most vulnerable counties appear in the southern half of the nation (Figure 2), stretching from south Florida to California—regions with greater ethnic and racial inequalities as well as rapid population growth.

Counties with SoVI scores greater than  $+1$  standard deviations are labeled as most vulnerable. They include a geographic mix of highly urbanized counties, large Hispanic and/or Native American populations, and socially dependent populations (those in poverty and lacking in education). A total of 393 counties (12.5 percent of the total) were classified in the most vulnerable category. The most socially vulnerable county in the nation is Manhattan Borough (part of New York City), largely based on the density of the built environment. This factor accounts for the placement of San Francisco County and Bronx County (New York City) among the top five most vulnerable counties as well. Two other counties round out the top five, but their vulnerability is derived entirely from different indicators. Kalawao, Hawaii is ranked second in overall social vulnerability based on three factors:

FIGURE 2

Comparative Vulnerability of U.S. Counties Based on the Social Vulnerability Index (SoVI)



age of residents (elderly), race/ethnicity (Asian and Native Hawaiian), and personal wealth (poverty). This is not surprising given the county's history as a former leper colony. In 1990, there were fewer than 200 residents of this county. Benton, Washington's social vulnerability is defined by its large debt to revenue ratio and reliance on high percentage employment in utilities. Again, this is not surprising when one considers that Benton County is home to Hanford Nuclear Reservation, a Department of Energy facility. A lower tax base (most of the county is in federal land ownership) coupled with the need to provide services helps to account for the relatively high debt to revenue ratio, thus increasing its social vulnerability.

Counties labeled as the least vulnerable (more than  $-1$  standard deviation from the mean) are clustered in New England, along the eastern slopes of the Appalachian Mountains from Virginia to North Carolina, and in the Great Lakes states. Topping the list of least vulnerable counties are Yellowstone National Park, MT; Poquoson, VA; Los Alamos, NM; Tolland, CT, and Moore, TN. The low social vulnerability score for Yellowstone National Park County is not a surprise given that the county is mostly in a protected status with a very small population that has little ethnic, racial, or gender diversity. The remaining counties are all relatively homogenous—suburban, wealthy, white, and highly educated—characteristics that lower the level of social vulnerability. The exception is Moore County, TN, located in the south central portion of the state. The county is also homogeneous, with predominately white, middle-class residents living in owner-occupied housing who are employed in technical, sales, or executive positions. The county has relatively low unemployment as it is home to the Jack Daniel's Distillery, the primary source of employment in the area.

### Using SoVI to Predict Disaster Impacts

To initially test the reliability and usefulness of the SoVI, we examined the number of presidential disaster declarations by county for the 1990s. We recognize that these declarations represent larger, singular events rather than smaller, more chronic losses, and are often seen as political rewards rather than risk or impact-driven responses (Downton and Pielke, 2001). However, as a proof of concept, the relationship between the frequency of disaster declarations per county and its level of social vulnerability (as measured by the SoVI) might yield some useful insights.

We conducted a simple correlation between the frequency of presidential disaster declarations by county (during the 1990s) and the SoVI index score. There is a weak but negative relationship ( $r = -0.099$ ,  $s = 0.000$ ) between the number of disaster declarations and higher SoVI scores. This initially suggests no discernible trend in the relationship between presidential declarations and the degree of social vulnerability. Nationally, the average

number of presidential disaster declarations per county is 2.4, yet among the most vulnerable counties (Figure 2), the mean is 1.97, while for the least vulnerable the mean number of disaster declarations is 2.52. These differences, however, are not statistically significant.

## **Conclusions**

There is no consensus within the social science community about social vulnerability or its correlates. Using the hazards-of-place model of vulnerability, we suggest that social vulnerability is a multidimensional concept that helps to identify those characteristics and experiences of communities (and individuals) that enable them to respond to and recover from environmental hazards. The correlates are largely derivative from local case studies of disasters and community responses. There have been few, if any, attempts to develop larger theoretical or conceptual understandings of comparative indicators of social vulnerability, despite the clear need to develop such a robust and replicable set.

The factors identified in the statistical analysis are consistent with the broader hazards literature and not only demonstrate the geographic variability in social vulnerability, but also the range in the underlying causes of that vulnerability. As a comparative measure, this methodology works quite well, explaining about 76 percent of the statistical variance in U.S. counties, using 11 independent factors. Having said this, we realize that the SoVI is not a perfect construct and more refinements are necessary. This is very clear based on the lack of correlation with presidential disaster declarations, which may be a function of the SoVI, but is more likely a function of the frequency and location of disaster events as well as the political process involved in the declaration process itself.

The SoVI can be coupled with hazard event frequency (number of natural hazards events, for example) and economic loss data to further examine those individual factors that are the most important contributors to dollar losses. This could be done on an individual hazard basis (e.g., floods, hurricanes) or by specific time period for all hazards. Not all factors are equal, and the need to develop a defensible weighting scheme is important. But what should determine those relative weights?

The next step is to examine how the overall social vulnerability as measured by the SoVI has changed over time and space. To do that requires a historical reconstruction of the variables used in this analysis. In this way, one can monitor changes in the total social vulnerability score as well as its underlying dimensions from a set period, 1960 onward, for example. Further, the analysis can be projected into the future (in this case using Census 2000 and beyond) using this analog data to develop realistic scenarios of potential future vulnerabilities.



This methodology also can support specific subsetting of counties, such as coastal or riverine counties, to ascertain similarities and differences in relative levels of social vulnerability. The relationship between the level of social vulnerability and biophysical risk is the obvious next step. How well do the counties match up? Are those counties most exposed (higher hazard potential or greater biophysical risk) also the most socially vulnerable? In adding a physical component, vulnerability can be examined not just as a social or a biophysical phenomenon, but as a complex interaction of the two. This integrative step will help advance our understanding of vulnerability science at the local, regional, and national scales. The SoVI can assist local decisionmakers in pinpointing those factors that threaten the sustainability and stability of the county (or community). Using this index in conjunction with biophysical risk data, means that mitigation efforts can be targeted at the most vulnerable groups or counties. The development and integration of social, built environment, and natural hazard indicators will improve our hazard assessments and justify the selective targeting of communities for mitigation based on good social science, not just political whim.

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