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# Assessing the Relationship Between Social Vulnerability and Community Resilience to Hazards

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## Abstract

This article contributes to the disaster literature by measuring and connecting two concepts that are highly related but whose relationship is rarely empirically evaluated: social vulnerability and community resilience. To do so, we measure community resilience and social vulnerability in counties across the United States and find a correlation between high levels of vulnerability and low levels of resilience, indicating that the most vulnerable counties also tend to be the least resilient. We also find regional differences in the distribution of community resilience and social vulnerability, with the West being particularly vulnerable while the Southeast is prone to low levels of resilience. By looking at both social vulnerability and community resilience, we are able to map communities' social risks for harm from threats as well as their capacities for recovering and adapting in the aftermath of hazards. This provides a more complete portrait of the communities that might need the most assistance in emergency planning and response, as well as whether such interventions will need to be tailored toward reducing damage or finding the path to recovery.

### Keywords

Social vulnerability; Community resilience; Disasters; Hazard indicators

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## 1 Introduction

Research into vulnerability and resilience to hazards is increasingly important in a world with more extreme weather patterns and a global occurrence of technological disasters. Understanding how communities differ in respect to the amount of damage that threats can potentially inflict, as well as the resources and strategies available to communities to recover, is central to helping people plan for and rebound from disasters. Social vulnerability and community resilience are two essential concepts for evaluating both communities' risks and coping capacities when dealing with hazards.

The concept of vulnerability is used across a variety of fields and disciplines, including disaster management, development, economics, sociology, anthropology, geography, health, global change, and environmental studies (Alwang et al. 2001; Cutter 1996). Perhaps because of this widespread application, there is no consensus on a precise definition for vulnerability. For instance, in a review of the literature, Cutter (1996) documents 18 different definitions of vulnerability, varying from the degree to which different classes of society are differentially at risk, to vulnerability being a function of the costs and benefits of inhabiting areas at risk from natural disaster (pp. 531–532). In this article, we narrow our focus to the disaster management literature where vulnerability usually incorporates the traits and conditions that make humans vulnerable (e.g. social structures and inequalities) in coping with disasters rather than simply the likelihood of experiencing a disaster (Alwang et al. 2001). Looking at social conditions, such as level of development, rather than just risk exposure is key to understanding potential losses from hazards. For instance, the least developed countries represent 11 % of the population exposed to hazards yet account for 53 % of all casualties; contrast this with the most developed countries which represent 15 % of the population exposed to hazards yet only represent 1.8 % of casualties (Peduzzi et al. 2002, 2009). Clearly social systems, development, and infrastructure, rather than simply risk exposure, figure prominently into loss and destruction from threats and disasters. As Morrow (1999) notes, "Disaster vulnerability is socially constructed, i.e., it arises out of the social and economic circumstances of everyday living" (p. 1).

That social systems play a prominent role in human vulnerability to hazards is central to the idea of social vulnerability. Cutter (1996) describes social vulnerability as including "the susceptibility of social groups or society at large to potential losses (structural and nonstructural) from hazard events and disasters" (p. 530). Commonly used factors to measure social vulnerability include economic, demographic, and infrastructure traits of a community (Cutter et al. 2003). Understanding what drives social vulnerability is an essential step toward helping communities to acquire the resources and strategies needed to minimize losses from disasters.

While vulnerability speaks to the conditions that make communities susceptible to harm, resiliency refers to coping with and recovering from a hazard that has already occurred. Like its sister concept of vulnerability, resiliency is used across a variety of fields, including physics, engineering, economics, ecology, psychology, sociology, anthropology, public health, geography, and disaster management (Bruneau et al. 2003; Norris et al. 2008). At a general level, resilience refers to an ability to recover from disturbances. At a more specific

level, resilience can pertain to items as divergent as the elasticity of physical materials to individuals' psychological reactions to trauma. For example, psychological resilience is used to describe whether people are able to positively adapt in situations of stress and adversity (Luthar et al. 2000; Rutter 1987). Ecological resilience is a measure of the ability of ecological systems to absorb changes and disturbances without having to redefine self-organizing processes and structures (Gunderson 2000; Holling 1973). If ecosystems are pushed passed these limits of resiliency, or thresholds, they may flip completely into a new system, such as clear lakes becoming permanently murky with algae blooms or grasslands turning into woodlands. In turn, these definitions of resilience can be exported to social systems to understand how communities absorb and adapt to adversity or disturbances like disasters. Walker and Salt (2006) use a similar definition to ecological resilience when they describe resilience as the capacity of a system to absorb disturbances and still retain its basic structure and function. However, this definition is not just applicable to ecological systems but also to human social systems, as well as the interplay between the two, termed social-ecological systems.

Community resilience refers to how communities are able to cope with, recover from, or adapt to hazards. Paton and Johnston (2001) describe community resilience as a community being able to "bounce back" by recovering from adversity using its own resources and potentially even experiencing growth in response, and they point to a number of components of resilience, including personal and environmental characteristics, but also a sense of community, feelings of efficacy, and coping strategies. Norris et al. (2008) provide a similar definition in describing community resilience as a process that connects a set of networked adaptive capacities to a positive trajectory of functioning and adaptation following disturbances (p. 131). Sherrieb et al. (2010) state that resources fostering resiliency constitute "part of the social and economic fabric of the community" and warn that communities lacking resilience may result in delayed recovery and increased health and mental health problems across the community (p. 228). Additionally, resilient communities may not only recover but grow in the process, such as by adapting, learning, and changing in response to threats (Cutter et al. 2008; Paton and Johnston 2001).

Consequently, resilience can be viewed as a process, rather than an outcome, that emphasizes adaptability rather than simply stability (Norris et al. 2008). Holling (1973) differentiates resilience from the idea of stability, which refers to systems returning to an equilibrium state after a temporary disturbance. Communities' abilities to recover from major adversity may make it impossible to return to exact pre-event conditions. Indeed, with resilience, communities might remake themselves, such as emphasizing a different industry or economic sector. This makes resilience more about overcoming adversity and recovering in general than about recreating communities exactly as they were before the disasters or hazards occurred. Embracing change is at the heart of resiliency (Walker and Salt 2006).

Social vulnerability and community resilience can be viewed as separate but often linked concepts (Cutter et al. 2008). Vulnerability speaks to the inherent qualities of a social system that exist before events like disasters occur that contribute to the amount of risk of exposure as well as the degree of harm, while resilience is the conditions that help social systems to absorb, cope with, and adapt to hazards and disasters (Cutter et al. 2008). While multiple

scholars note the conceptual links between these two indices, few have empirically investigated the relationship between community resilience and social vulnerability (for an exception see Sherrieb et al. 2010). This raises the question: are the most vulnerable communities also the least resilient? Or are there communities that are strong in one area, but weak in the other? There appears to be an implicit assumption in the literature that communities low on community resiliency are also high on social vulnerability, but this has yet to be evaluated on nationwide scale. Mapping the relationship between social vulnerability and community resilience could provide important information in targeting resources and guiding the actions of decision-makers seeking to help communities avoid or weather losses from threats.

In this article, we empirically evaluate the relationship between community resilience and social vulnerability in counties across the United States and are the first study to do so nationwide. To test how these concepts are related, we conduct factor analyses on variables from county-level data in the United States to create community resilience and social vulnerability indices and then assess how the two indices are correlated using Pearson and Spearman correlation coefficients. We also look at regional variation in community resilience and social vulnerability to better understand the areas that might be most affected by hazards like disasters. More specifically, we use MANOVA and *t*-tests to examine whether there are differences in the Northeastern, Southern, Midwestern and Western regions of the United States. We also utilize a measure of spatial autocorrelation— Moran's I—to assess whether counties that are less resilient and more vulnerable, and vice versa, tend to cluster spatially. Because our data is specific to the United States, we recognize that the types of measures used and the relationships found may not be applicable worldwide, although it does provide an initial look at how these two concepts might be related, particularly in contexts similar to those found in the United States.

We find a correlation between high levels of vulnerability and low levels of resilience, suggesting that indeed there is a trend where the most vulnerable counties are also the least resilient. Additionally, geographic clustering is evident, with high-risk counties being located near each other and low-risk counties also being spatially proximate. Further, there are regional differences in the occurrence of vulnerability and resiliency, with the West being particularly weak in its susceptibility to harm from hazards and the Southeast scoring low on its ability to recover from threats. While vulnerability and a lack of resiliency often co-occur, we also find exceptions, where some counties are high on both social vulnerability and community resilience and others are low on both vulnerability and resilience. This supports the idea that there are conceptual distinctions between vulnerability and resilience and suggests that researchers should treat them as distinct but related indices. In turn, determining if a community or region is either resilient or vulnerable can provide important information for on the ground application of strategies and programs to assist local areas in preparing for or recovering from disasters.

## 2 Measuring Social Vulnerability and Community Resilience

One of the primary challenges in studying both social vulnerability and community resilience is determining the best route for measuring these concepts. A multitude of factors

determine the vulnerability or resiliency of a particular community, raising questions about the best way to capture these concepts empirically.

### 2.1 Social Vulnerability

Just as definitions of social vulnerability vary, so do its indicators. However, there are trends in how social vulnerability is typically conceived. There may be generic determinants of vulnerability, such as poverty, health status, and economic inequality, or determinants that are specific to a particular area or threat, such as the number of storm shelters or the stringency of building codes in a disaster-prone region (Brooks et al. 2005). Another approach to measuring social vulnerability is to include both residents' traits and community characteristics. Adger (1999) makes a distinction between vulnerability at an individual or household level (such as social status and resource access) and collective vulnerability at a community, regional, or national level (such as markets, institutions, social security, insurance, infrastructure, and income). Consequently, to understand community vulnerability, we can look at both aggregate measures of individual and household traits (e.g. race, income, and age) as well as infrastructure and community-level characteristics.

At the individual or household level, core components of vulnerability tend to include socioeconomic status, gender, race, ethnicity, and age and aggregate measures of these factors can speak to social vulnerability (Cutter et al. 2000, 2003, 2008; Hewitt 1997; Peacock et al. 1997; Phillips et al. 2010; Wisner et al. 1994). These traits may be or more or less present in particular neighborhoods, indicating potential obstacles for communities. The poor are likely to have fewer resources and safety nets than the rich, including access to resources like health insurance, hazards insurance, savings, transportation, and quality housing (Dash et al. 2010). Women and minorities may also have fewer resources and face more barriers to recovery than men and whites. Racial minorities have increased risks for environmental injustice, which can place them in closer proximity to environmental hazards (Stretesky and Hogan 1998). For example, American Indians are a vulnerable group, in the United States with almost a third of the population living in poverty (28.4 % as compared to the nation as a whole at 15.3 %) and a similar number lacking health insurance (29.2 % as compared to the overall population at 15.5 %) (U.S. Census Bureau 2011). While race and ethnicity globally contribute to social vulnerability through a lack of access to resources, careful consideration must be given to how disadvantaged racial and ethnic groups are socially constructed within certain regions. In the United States, the racial and ethnic groups utilized by the U.S. Census Bureau are regularly used as proxies for experiences of unequal access to key resources due to differences in language, culture, educational levels, or other areas of discrimination. In other regional settings, other divisions of ethnicities, immigration status, or social class may be more relevant categories of disadvantage (de Oliveira Mendes 2009; Fekete 2009). For the purposes of our analyses, we utilize the U.S. Census categories for race (White, Black or African American, American Indian and Alaska Native, and Asian) and ethnicity (Hispanic).

Women may experience greater declines in income than men after disasters, and mothers may be adversely affected by limited access to childcare post-disasters (Enarson 2010). The elderly are particularly at risk for death or injury from disasters and may have health and

mobility problems that compound the harm caused by hazards (Peek 2010).Additionally, those with lower levels of education or language barriers may have less access to warning information or experience more difficulties navigating recovery programs. Renters are less likely to have control over their buildings, lacking the ability to install proper protections against disasters or dictate issues of repair (Morrow 1999). Families with young children, people dependent on social services, or populations with special needs, such as the homeless, may also be particularly vulnerable to disruptions and need support after disasters (Cutter et al. 2003; Morrow 1999). Also, children may require additional resources in response to disasters, such as special supplies like diapers, formula, and baby food (Enarson and Morrow 1997; Peek 2010). Even attitudes of individuals and households can affect vulnerability, including a sense of empowerment or knowledge about potential hazards (Mustafa et al. 2011).

At the macro-level, a second set of factors affect vulnerability. These structural characteristics can aid or hinder the ability of residents to survive and recover from a disaster. Such traits include the extent and construction quality of infrastructure such as roads, buildings, houses, sewers, and bridges, whether the community is rural or urban, land use decisions, diversity and risk in occupational sectors, economic health, unemployment rates, and access to services like medical care and hospitals (Cutter et al. 2000, 2003; Passerini 2010). Poorly constructed buildings or dams could increase the amount of damage caused by a disaster. For instance, public housing that lacked proper hurricane protection for windows forced thousands of residents into tent cities and temporary housing after Hurricane Andrew (Morrow 1999). Similarly, older manufactured housing can be particularly vulnerable to wind damage from hurricanes and tornadoes (Dash et al. 2010). Communities with few roadways and a lack of hospitals could delay residents' ability to receive the medical care they need in response to disasters. Economies that are weak, have high unemployment rates, or revolve around a single sector, like fishing, may be particularly vulnerable to losses from a disaster, as residents struggle to find work post-disaster. Densely populated areas with large, high-occupancy buildings may experience particularly egregious outcomes to disasters like earthquakes (Hewitt 1997). Some studies go beyond the community level to the national level, where even higher-order factors are taken into consideration, such as elements of governance, including government effectiveness, civil liberties, and political rights (Brooks et al. 2005). Even at the community level, groups that are politically marginalized or live in unincorporated or rural areas may find it difficult to secure the attention of political powers (Morrow and Peacock 1997). Thus, in assessing social vulnerability, scholars often look at residents' characteristics, as well as the environment they are embedded in, to gain a full portrait of the extent of potential losses that could occur in a disaster scenario.

A principal study in measuring social vulnerability is Cutter et al. (2003) work on identifying and employing a variety of indicators of social vulnerability. These indicators led to composite factors that formed the underlying dimensions of social vulnerability: personal wealth, age, density of the built environment, single-sector economic dependence, housing stock and tenancy, race, ethnicity, occupation, and infrastructure dependence. We rely on the principal components identified in this study, as well as related studies, in developing our own measures to assess the nationwide relationship of social vulnerability and community

resilience. Also, similar to Cutter et al. (2003), we separate geographic context and biophysical vulnerability to hazards from social vulnerability (Cutter 1996), and focus only on social vulnerability. Risks such as being in a hurricane-prone region are more tied to the natural world than to social systems and are not something humans have the capacity to change. Some institutions, like the World Health Organization, also emphasize modifiable environmental factors that could be realistically amenable to change through means such as technologies, policies, and health measures for problems like the environmental burden of disease (Prüss-Üstün and Corvalán 2006).

### 2.2 Community Resilience

The ability to recover from disasters contains an economic component, similar to social vulnerability, but also a social component. At the core of recovery is the ability of community members to work together to overcome obstacles caused by the disaster in order to embark on the road to recovery. Thus, community resilience takes a communal perspective to coping with disasters and encompasses ideas like problem-solving, efficiency, and adaptability. Coles and Buckle (2004) state that for effective recovery to occur, affected communities need to actively participate in the recovery process and have the capacity, skills, and knowledge to participate in a meaningful way. In looking at community resilience to volcanic hazards, Paton et al. (2001) focus on the variables of a sense of community, coping style, and self-efficacy. A sense of community, or feelings of belonging for people and places, may foster stronger social support networks and increase involvement in community disaster responses. Individuals high on self-efficacy and who focus on confronting the problem as a coping style may be more resilient in the face of disasters. The authors find support that efficacy and problem-focused coping can facilitate resilience.

Bruneau et al. (2003) describe four properties that are key to the resiliency of systems: robustness, redundancy, rapidity, and resourcefulness. Robustness pertains to the ability to weather stress without deteriorating or losing function, redundancy is the degree to which components of a system can be substituted if one element is harmed, rapidity is the ability to respond quickly to achieve goals and reduce losses, and resourcefulness is the capacity to establish priorities, identify problems, and mobilize resources to solve them in the face of hazards. We can see these traits in operation in communities; for instance, if one hospital is damaged, but there is another located nearby to provide services, this can help residents get the help they need after a disaster. Walker and Salt (2006) note that while efficiency and optimization call for the deletion of redundant items, such redundancy is vital to a system's resiliency. Communities with diverse economic sectors may be more robust to harm than those reliant on a single industry and such diversity in resources may help to solve problems brought about by the disaster.

Norris et al. (2008) build on the ideas of robustness, redundancy, and rapidity to identify four sets of networked adaptive capacities—Economic Development, Social Capital, Information and Communication, and Community Competence—that facilitate a community's ability to recover from severe stress. Important components to economic development include the level and diversity of economic resources as well as how equally they are distributed. These concepts can be operationalized with variables such as the

median household income, employment/population ratio, income equity, and occupational diversity, among other factors (Sherrieb et al. 2010). The social capital component includes measures of social support, social embeddedness, organizational ties, citizen participation, a sense of community, and attachment to place. It has been operationalized through measures regarding rates of two parent households, sports/arts and civic organizations, voters in a presidential election, religious adherents, net migration, and property crime (Sherrieb et al. 2010). Information and communication refer to responsible media, trusted sources of information, and the skills and systems in place for informing the public, as well as communal narratives that allow groups to frame experiences and share meanings. Lastly, community competence speaks to a community's ability to organize collectively to identify and address problems in ways that are efficacious, creative, flexible, and empowering.

We utilize the work of Norris et al. (2008) and Sherrieb et al. (2010) in identifying and operationalizing community resilience in our study. We focus on indicators that tap into two core components –economic development and social capital—of community resilience. More specifically, the economic development component includes measures of county-level employment, income, occupations, taxes, and resource equity, while the social capital component includes measures of household composition, civic organizations, voting behaviors, religious adherence, migration, and crime.

## 3 Methods

In order to empirically evaluate the relationship between social vulnerability and community resiliency, we first turned to the literature on disaster preparedness and selected two prominent and currently utilized indicators representing the two concepts: the Social Vulnerability Index (SoVI) and the Community Resiliency Index (CRI). We ran a series of tests to examine their relationship. Our first step was to reconstruct the SoVI following the methodology laid out by Cutter et al. (2003) and further developed by the Hazards and Vulnerability Research Institute at the University of South Carolina (2011). Methodological guidelines published by the Institute are available online, although the data comprising the comparative metric are not publically available. Although scores for each county in the United States are publically available, we chose to conduct our own factor analysis to assure our accurate use of indicators. Second, we collected the variables outlined in Sherrieb et al. (2010) to construct the CRI for each county in the United States. Although the ideal geographic representation of the community in which vulnerability and resiliency truly operates is likely smaller than politically-drawn county lines, the availability of socioeconomic data to operationalize the theoretical mechanisms is limited to this level. We then utilize several statistical approaches to understand how the CRI and SoVI operate across counties in the United States, including correlations, *t*-tests, and the Moran's I, which is a measure of spatial autocorrelation.

### 3.1 Social Vulnerability Index

The data for the calculation of the SoVI came from a number of sources. The bulk of the data were drawn directly from the 2000 U.S. Census website, using American Fact Finder. We also utilized the USA Counties website, which provides data at the county level from a

variety of secondary sources. Finally, we also utilized the 2007 edition of the City and County Data Book, which amasses county level data from the U.S. Census Bureau and other federal statistical bureaus, governmental administrative and regulatory agencies, and private research bodies (U.S. Census Bureau 2007). Following the 30 variable recipe provided by the Hazards and Vulnerability Research Institute (2011), we collected the requisite data and assembled each variable for 3,143 counties. Missing values were imputed by substituting the variable's median value for each enumeration unit. The variables were then standardized using z-scores ($z = (x - \mu)/\sigma$).

With PROC FACTOR in SAS version 9.4, a principal components analysis was performed using a varimax rotation. Extreme outliers (counties with a z-score larger than 5 for any variable) were not included in the principal components analysis; this excluded 199 counties. We selected an eigenvalue threshold for factor extraction at 0.97 as the subsequent factor's eigenvalue dropped to 0.90. Our methodology differed slightly from that of Cutter et al. (2003); we selected one factor with an eigenvalue less than one, we excluded outliers from the principal components analysis, and we substituted medians rather than means for missing values. By excluding the 199 counties with extreme values on one or more variable from the principal components analysis, we sought to obtain a representation characteristic of the majority of the counties rather than of the extreme ones. Similarly, we substituted medians rather than means for missing values in order to avoid substituting extreme values. Our methodology led to eight factors rather than the seven of Cutter et al. (2003).We have one factor that consists of only one indicator—percent of the population that is Native American—but this factor is important for assessing vulnerability, particularly in the West and Midwest regions. Further, 22 % of Native Americans live in reservations or other trust lands (U.S. Census Bureau 2011), resulting in a geographic concentration that is important for understanding the vulnerability of particular counties. We qualitatively examined the factors and assigned a positive or negative value such that negative values are seen as reducing a county's vulnerability and positive values as contributing to overall vulnerability (see Table 1).We then computed factor scores for all counties, including the 199 counties with outlying data.

### 3.2 Community Resilience Index

To calculate the Community Resilience Index (CRI), we follow the method provided by Sherrieb et al. (2010: 240) for the variables included in the Index's two components: an Economic Development Index and a Social Capital Index. Specifically, the economic development component includes measures of county-level employment, income, occupations, taxes, and resource equity. The social capital component includes measures of household composition, civic organizations, voting behaviors, religious adherence, migration, and crime. The data for the calculation of the CRI came from a number of sources. We used data on voting during the 2008 presidential elections provided by *The New York Times*. Demographic data were drawn directly from the 2000 U.S. Census website, using American Fact Finder. We used the *USA Counties* website and the American Community Survey 2010 5-year estimates for the remaining social indicators. Data on religious adherents were obtained from the Association of Religion Data Archives at the

county level. Finally, we used the Gini coefficients as calculated and provided by Dr. Mark L. Burkey of North Carolina A&T in the School of Business and Economics.

Missing values were imputed by substituting the variable's median value for each enumeration unit by first subtracting medians in each variable and replacing missing values with zeros. Variables were then standardized using a z-score standardization ($z = (x - \mu)/\sigma$) resulting in scores ranging from 0 to 1. Scores for the seventeen variables collected for 3,139 counties were then averaged within the 10-variable Economic Development Index and the 7-variable Social Capital Index to create composite scores, which were then added together to produce the Community Resilience Index developed by Sherrieb et al. (2010). Like their originators, we assume that the design of the Economic Development Index and the Social Capital Index are of equal weight.

### 3.3 Relationship Between Social Vulnerability and Community Resilience

To assess the relationship of the Social Vulnerability Index to the Community Resilience Index, we used the scores from 3,136 counties with data available for both indices. We related the SoVI to the negative CRI to determine whether increased vulnerability was associated with decreased resilience. We computed Pearson and Spearman correlation coefficients and asymptotic 95 % confidence intervals via Fisher's z-transformation. Next we conducted a multivariate analysis of variance (MANOVA), which permits analyses of multiple dependent variables, to examine whether there are any differences between the means of the CRI and the SoVI across regions (Northeast, Midwest, South or West) of the United States (Mardia et al. 1979). Because the MANOVA is significant, indicating at least one difference across the groups exists, we then conducted pairwise *t* tests to compare regions on the CRI and the SoVI. The *t* tests provide more specific information about which groups differ and the nature of those differences.

We constructed nationwide maps of percentiles for the SoVI and also for the negative CRI using ESRI's ArcMap 10.1 and a cartographic boundary file from the 2000 U.S. Census (co99_d00.shp, available at http://www.census.gov/geo/maps-data/data/cbf/cbf_counties.html). To construct a map representing the association between the two indicators, we assigned each county to one of five colors depending on whether the SoVI and negative CRI were within, above, or below the interquartile range. We used red if both were above, blue if both were below, yellow if the SoVI was below but the negative CRI was above, and green if the SoVI was above but the negative CRI was below. All other counties were colored gray. To assess whether regions of high vulnerability and low resilience, and vice versa, tend to cluster, we computed Moran's I, which is a measure of spatial autocorrelation (Waller and Gotway 2004). While examining regional differences paints a broad portrait of where high vulnerability or low resilience areas tend to be in the United States, the Moran's I can assess whether counties high or low on vulnerability and resilience are likely to be connected to counties with similar profiles. This allows us to identify whether clusters of high or low risk areas occur at a more local level, regardless of the region in which these counties are embedded.

## 4 Results

Our results support the idea that there is a relationship between social vulnerability and community resilience. For the 3,136 counties with data on both the SoVI and the negative CRI, the SoVI scores had a mean of 0.358 and a standard deviation of 4.02. The mean was substantially greater than zero due to inclusion of the outliers when constructing factor scores. The negative CRI scores had a mean of 0.001 and a standard deviation of 0.769. The first part of the CRI, the Economic Development Index, ranged from −1.97 to 3.73, with a mean of approximately zero and a standard deviation of 0.566. The second part of the CRI, the Social Capital Index, ranged from −1.63 to 4.82, with a mean of approximately zero and a standard deviation of 0.510. A scatterplot relating the negative CRI and the SoVI for the 3,136 counties is shown in Fig. 1. The Pearson's correlation was 0.386 (0.356, 0.416; $p <$ .001), and the Spearman's correlation was 0.554 (0.529, 0.577; $p <$.001).

The results also indicate that there are regional differences in levels of social vulnerability and community resilience. The results in Fig. 1 are color coded to represent the Census Regions, which are utilized by the U.S. Census Bureau to group the states and the District of Columbia into areas for the purposes of presenting census data. There are four census regions—Northeast (red), Midwest (green), South (dark blue), and West (light blue). In Fig. 2, the squares are the centers of the four regions' bivariate distributions, while the ellipses represent the 95 % probability contours for each of the four region's bivariate distributions. The ellipses are color-coded to represent the four census regions in the same manner as Fig. 1. The MANOVA to assess the effect of region (Northeast, Midwest, South, and West) on the CRI and SoVI returned an F statistic of 145 (6, 6,264) with a $p$ value <.001, indicating that the indices differed substantially by region. The nationwide maps are presented in Figs. 3, 4, 5. From Fig. 3, we observe that the SoVI scores are highest in the West and parts of the Southeast (and also Alaska and Hawaii), whereas they are lowest in the Northeast and Midwest. This is reflected in the SoVI regional means, which are highest in the West and lowest in the Midwest (see Table 2). Independent samples $t$-tests using a Welch correction to account for unequal variances indicated that these regional means of social vulnerability were significantly different ($p \leq .01$, two-tailed tests) for all pairings except the Northeast and Midwest. On the other hand, in Fig. 4 we see that the West does not score as poorly on the negative CRI, whereas the Southeast scores worse. We again observe higher levels of resilience in the Midwest and Northeast. Regional means of CRI indicate that the Northeast is particularly strong in its resiliency, while the South has the lowest levels of resiliency (see Table 2). Independent samples $t$-tests using a Welch correction to account for unequal variances indicated that the regional means of community resilience were significantly different ($p <$.001, two-tailed tests) for all pairings except the West and Midwest. The association map (Fig. 5) documents that the West and Southeast have several pockets with particularly high vulnerability and low resilience, whereas the Midwest and Northeast have several with particularly low vulnerability and high resilience. We observe some counties with discordant scores on vulnerability and resilience (those in yellow and green). Counties with high vulnerability and high resilience tend to coincide with major cities (e.g. Miami, San Francisco, Los Angeles, and New York).

To assess whether regions of high vulnerability and low resilience, and vice versa, tend to cluster, we computed Moran's I, which is a measure of spatial autocorrelation. We conducted separate analyses for red counties (those that had both SoVI and negative CRI indexes higher than 75 %) and for blue counties (those that had both SoVI and negative CRI indexes lower than 25 %). The results indicated that geographic clustering was evident for the most vulnerable and least resilient counties (Moran's I = 0.0909; Z = 59.62; $p$ <.001) as well as for the least vulnerable and most resilient counties (Moran's I = 0.1269; Z = 83.21; $p$ <.001). This suggests that rather than following random spatial patterns, there are both high-risk and low-risk regions of vulnerability and resilience, with the practical implication that emergency planners and authorities can identify and target resources to areas in need.

## 5 Discussion

We find that vulnerability and resilience tend to be correlated, indicating counties that are more susceptible to harm also lack the means to rebound effectively, while counties that are low on vulnerability also have resources that facilitate recovery. This is not surprising, as communities rich in resources are likely to have both protections from hazards as well as capital that can be mobilized in response to threats, while resource-poor communities are likely to lack safety-nets in preparation for and response to hazards. In particular, the Northern parts of the United States, particularly the Midwest and Northeast, were more resilient and less vulnerable than the South and West. This reflects national trends in resource and social capital distribution. The Northeast has the highest median household income in the country ($50,088) followed by the Midwest ($45,907), the West ($45,435) and the South ($38,680) (U.S. Census Bureau 2013). Further, while over half of the counties within the highest median household income range are found in the Northeast, Maryland and Virginia, 79 % of counties within the lowest income range are found in the South (U.S. Census Bureau 2013). Thus, in general, residents of the South have less access to resources when preparing for and rebuilding from disasters. Additionally, some of the highest high school dropout rates are found in the Southeast through Texas, an area termed the Southern dropout belt (Weissman 2013). Being an ethnic or racial minority can also affect vulnerability, and the majority of Blacks live in the South (Rastogi et al. 2011) while the majority of Latinos live in the West and South (Ennis et al. 2011). Similarly, the West is more vulnerable, in part, due to its high population of American Indians; according to the 2010 U.S. Census, fully 41 % of American Indians and Alaska Natives live in the West (Norris et al. 2012). The South also has the highest percentages of violent and property crime relative to other regions (Federal Bureau of Investigation 2012). Further, the West has the highest proportion of religiously unaffiliated people (Pew Forum 2008), and the South has the highest regional percent of female households without a spouse and with children (Simmons and O'Neill 2001). Thus, our results reflect other studies in finding regional differences in economic and social capital, with the conclusion that many of the strongholds of resilience and low vulnerability are located in the Northeast and Midwest while the West and South remain areas particularly vulnerable to harm from threats.

While our analysis provides broad portraits of regional differences, it also pinpoints areas that may not fit national trends. In looking at the ten counties with the worst combined levels of vulnerability and resilience, a surprising result emerges: half of the counties are located in

the Midwest in South Dakota. This is likely due to the increased vulnerability that emerges from American Indian communities, which comprise 8.9 % of South Dakota's population, as compared to 1.2 % of the population in the United States (U.S. Census Bureau 2014). These counties in South Dakota also have negative scores on the economic development and social capital indices, resulting in a lack of community resilience. This example also speaks to an advantage of assessing social vulnerability and community resilience in combination. In looking at the top ten counties of high social vulnerability, only one is in South Dakota, and for the top ten counties of low community resilience, two are in South Dakota; but by assessing the combined effects of vulnerability and resilience, we see five problematic counties in South Dakota emerge, identifying this as a more troublesome area that either the SoVI or the CRI separately would have indicated. Consequently, we can identify new at-risk areas that either index alone might have missed. Broadening the scope to the top 50 worst counties on combined resiliency and vulnerability reflects what we see in the maps, with the majority located in the South (34 counties), none in the Northeast, some in the West (7 counties), and some in the Midwest (9 counties). But again, a more detailed analysis reveals that of those 9 Midwest counties with the poorest resilience and vulnerability scores, 7 of the counties are located in South Dakota. In sum, one of the benefits of looking at social vulnerability and community resilience data in concert is that it can provide a tool for zeroing in on areas that are at-risk, proving important information for emergency planners to aid with directing resources and intervention programs to the places likely to need assistance when experiencing disasters or other threats.

Our results also indicate that while social vulnerability and resilience are correlated, they should be treated as distinct concepts. There were geographic differences in where vulnerability and resilience were most pronounced; while the West dominated in areas high on social vulnerability, the Southeast was particularly pronounced in regard to a lack of community resilience. Such differences in distributional patterns of the two indexes lend credence to the idea that social vulnerability and community resilience are separate but linked concepts.

Further, while distinctly in the minority, there were counties that had high levels of vulnerability but also high levels of resilience (72 counties) and counties that had low levels of both vulnerability and resilience (35 counties). While too small a number of counties to draw definitive conclusions, these case studies suggest potential avenues for future research. The majority of counties that benefited from low social vulnerability but were at risk due to low resilience tend to be located in the South (28 of the 35 counties in this category), indicating this might be a Southern phenomenon. Alternatively, there appears to be a trend where counties that are high on both vulnerability and community resilience are home to major cities. Counties housing Miami, Houston, Dallas, San Diego, Los Angeles, San Francisco, Las Vegas, Honolulu, Denver, Portland, Seattle, Chicago, Cleveland, Boston, Washington D.C. and New York all fall into this category. Urban areas are noted for vulnerability as high population densities can complicate evacuation plans (Cutter et al. 2003) and the built infrastructure of cities, such as large, high-occupancy buildings, can make them particularly vulnerable to certain types of hazards (Hewitt 1997). Major cities may also have increased risks for threats like terrorism (Harrigan and Martin 2002). Indeed, one of the factors of the SoVI includes the percent urban of the population as well as

population density. However, it is interesting that these cities, while scoring high on vulnerability, also demonstrated high levels of resilience. To the extent that resilience speaks to a community's ability to adapt and overcome challenges, urban areas might be particularly flexible. Urban areas have a variety of economic sectors and industries, allowing people damaged in one sector due to a hazard (e.g. the seafood industry affected by an oil spill) to find employment in another arena; an option less available to rural areas dependent on a single economic sector.

Another direction for future research is to include the likelihood of experiencing different hazards as an additional factor when mapping and identifying vulnerable areas. This would indicate whether areas with high vulnerability and low resilience are also prone to threats or disasters, increasing their level of risk even further. Additionally, depending on the nature of the hazard –such as whether it is a natural or technological disaster— it may be beneficial to tailor social vulnerability and community resilience indices that are specific to genres of threats. Some factors that increase vulnerability to natural disasters –like mobile homes being susceptible to wind damage from hurricanes and tornadoes—may be less relevant to other disasters, like oil spills. Additionally, factors that help communities to rebuild after natural disasters, such as civic organizations, may not be as useful in certain technological disasters; in the case of the latter, a multitude of organizations can spring up with different diagnostic and prognostic claims regarding a threat, exacerbating community in-fighting (Kroll-Smith and Couch 1990).

Lastly, while understanding where vulnerability and low resilience co-occur is important to identifying areas in need of assistance, it would also be of interest to see if such areas, when faced with hazards, actually receive the aid and support they require. Communities that are the most vulnerable and the least resilient are likely to be the strongest candidates for receiving external resources after a disaster. More vulnerable communities will have higher levels of losses due to a multitude of factors that exacerbate the harm caused by disaster, while more resilient communities may be able to mobilize internal resources, making them less dependent on outside aid. But paradoxically, disaster compensation systems (such as insurance claims or government aid programs) may require expertise and resources to navigate, making communities that lack these skills, or the networks and infrastructure to acquire such expertise, less able to successfully utilize these resources. This could make the communities that are the most vulnerable and the least resilient also the most unsuccessful at receiving external support, underserving those in most need of help.

## 6 Conclusion

In this article, we assess the relationship between community resilience and social vulnerability in counties across the United States and find a correlation between high levels of vulnerability and low levels of resilience. This study, then, helps to identify counties that are high-risk for incurring harm from threats and encountering obstacles in recovering from hazards. Morrow (1999) advocates for emergency planners and policy-makers to use community vulnerability maps to identify and work with high-risk areas in disaster preparation and response. Thus, understanding which areas are most in need of assistance can be beneficial in deploying programs that help prepare communities and mitigate harm

before disasters, as well as direct aid and resources to struggling areas after hazards. We also find that not all counties have parity in regard to vulnerability and resilience levels. By assessing vulnerability and resilience as related, but distinct, measures, we identify areas that are vulnerable but also resilient, and vice versa. This can help to target resources where they are most needed and determine the nature of intervention programs. Areas high on vulnerability may need particular attention in regard to emergency planning and preparation, while areas low on resilience may benefit most from programs that assist with rehabilitation and aid in the aftermath of disasters. In sum, assessing both social vulnerability and community resilience can help determine counties' unique situations in relation to hazards, potentially assisting emergency planners and authorities in addressing weak points and improving communities' overall ability to weather hazards.

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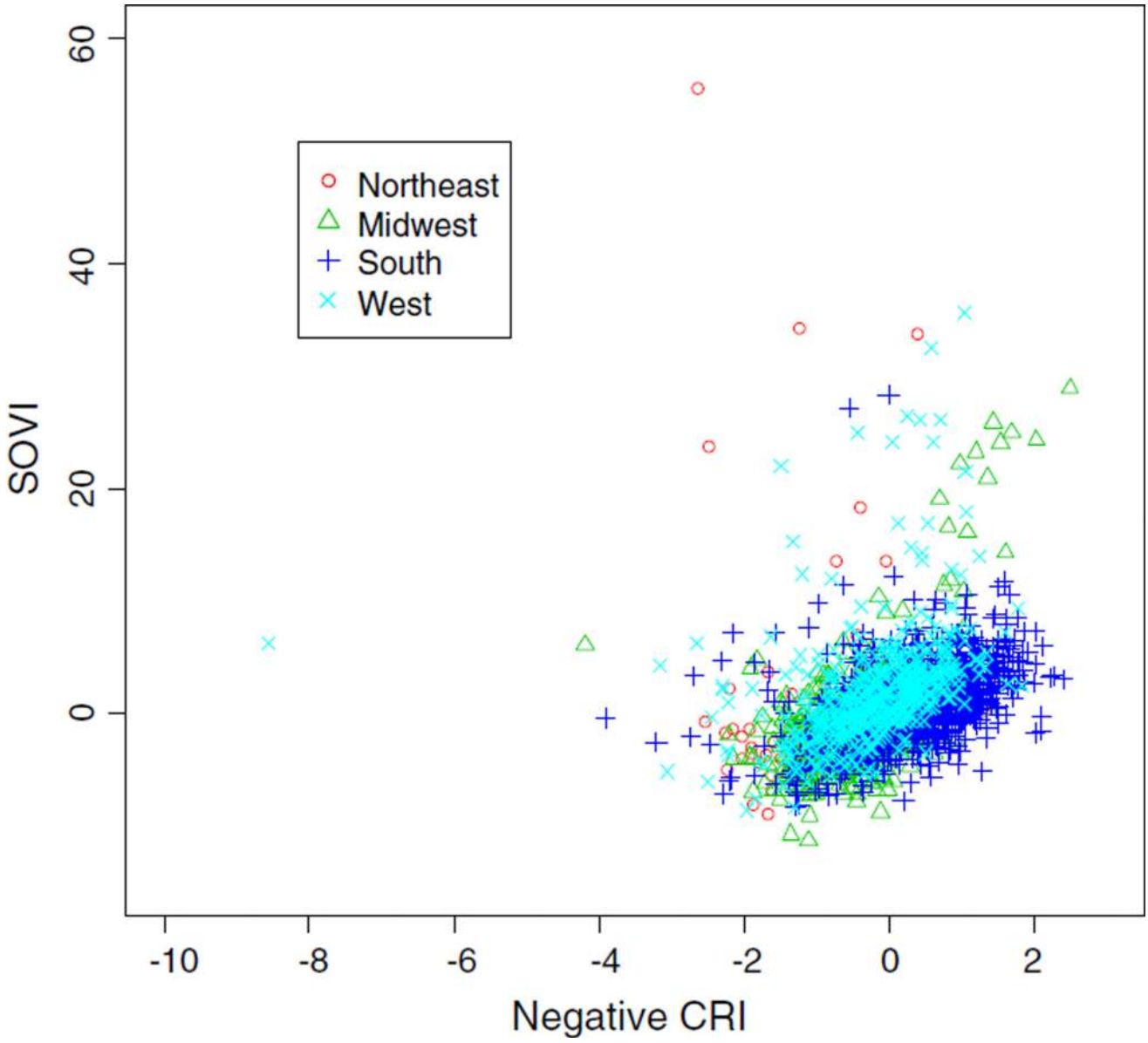


**Fig. 1.**
Scatterplot of SoVI and negative CRI scores

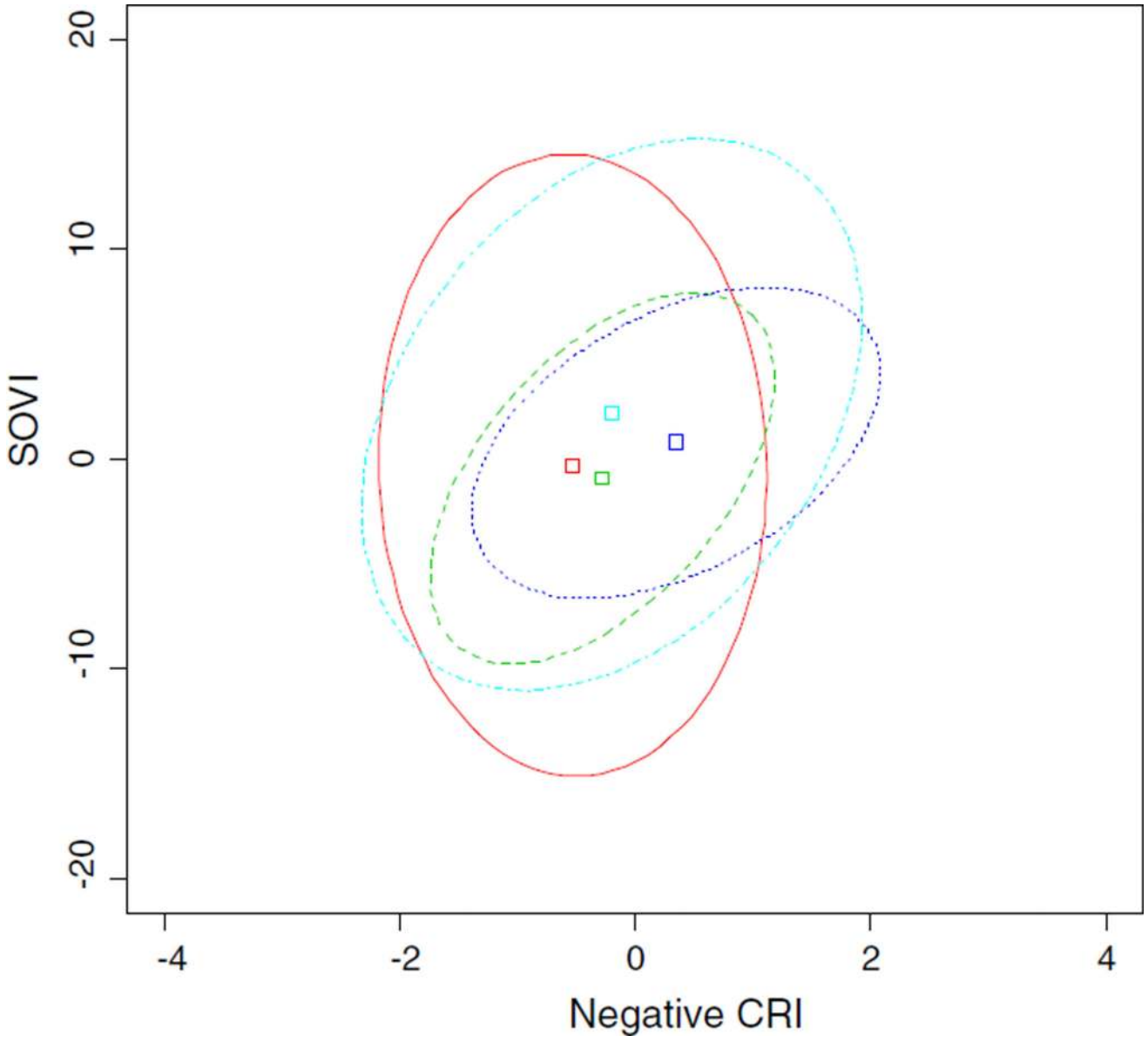


**Fig. 2.**
Intra-group variance of SoVI and negative CRI scores

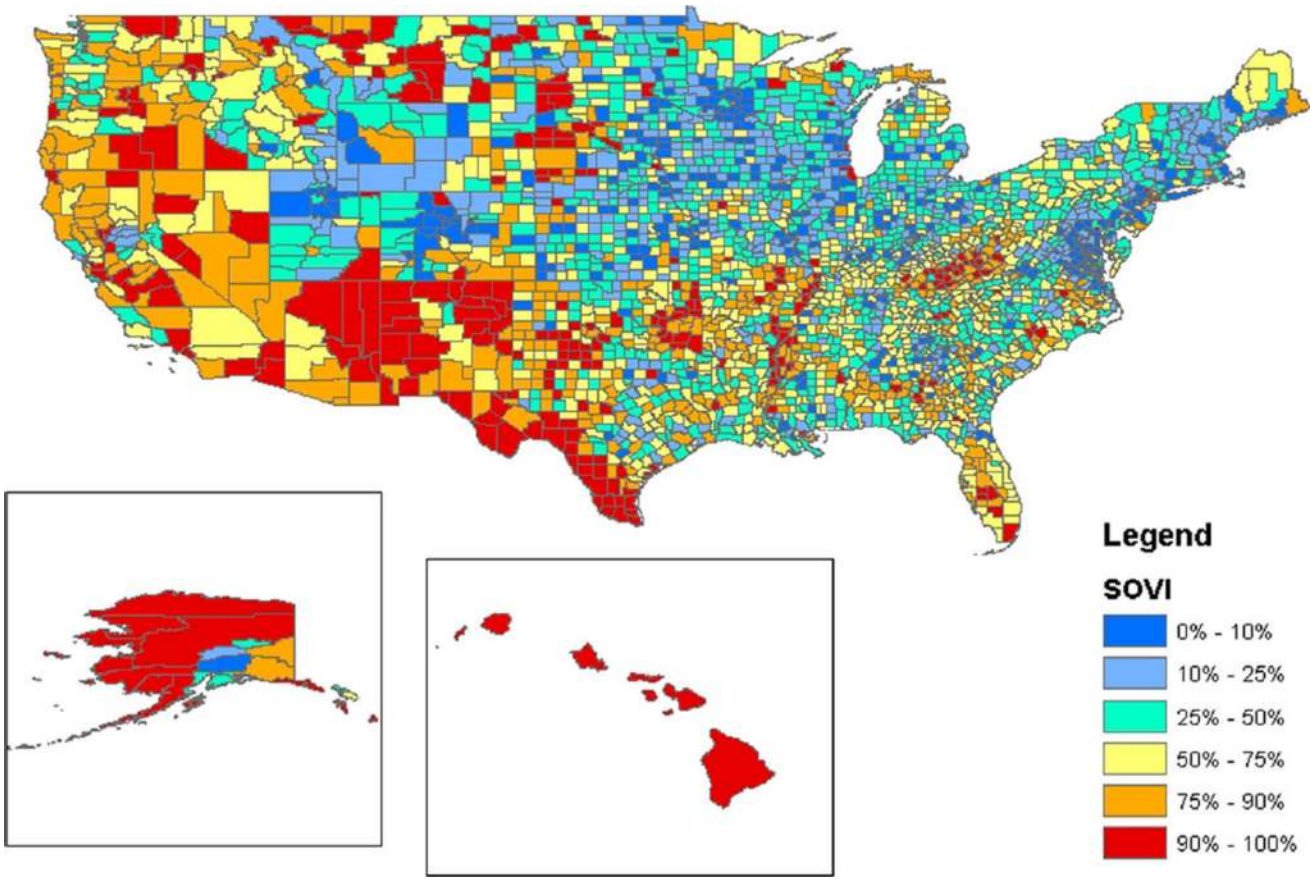


**Fig. 3.**
Map of county-level SoVI percentiles

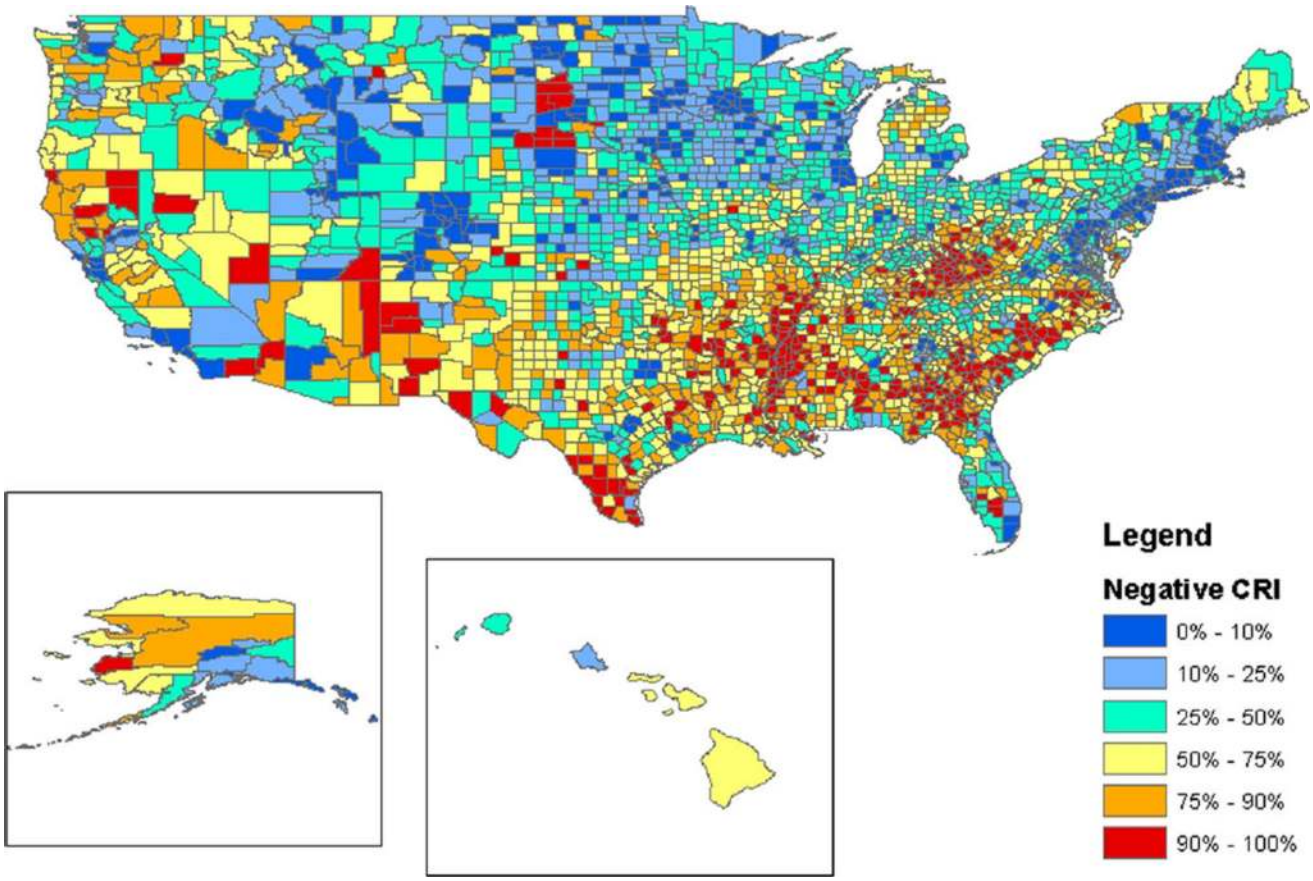


**Fig. 4.**
Map of county-level negative CRI percentiles

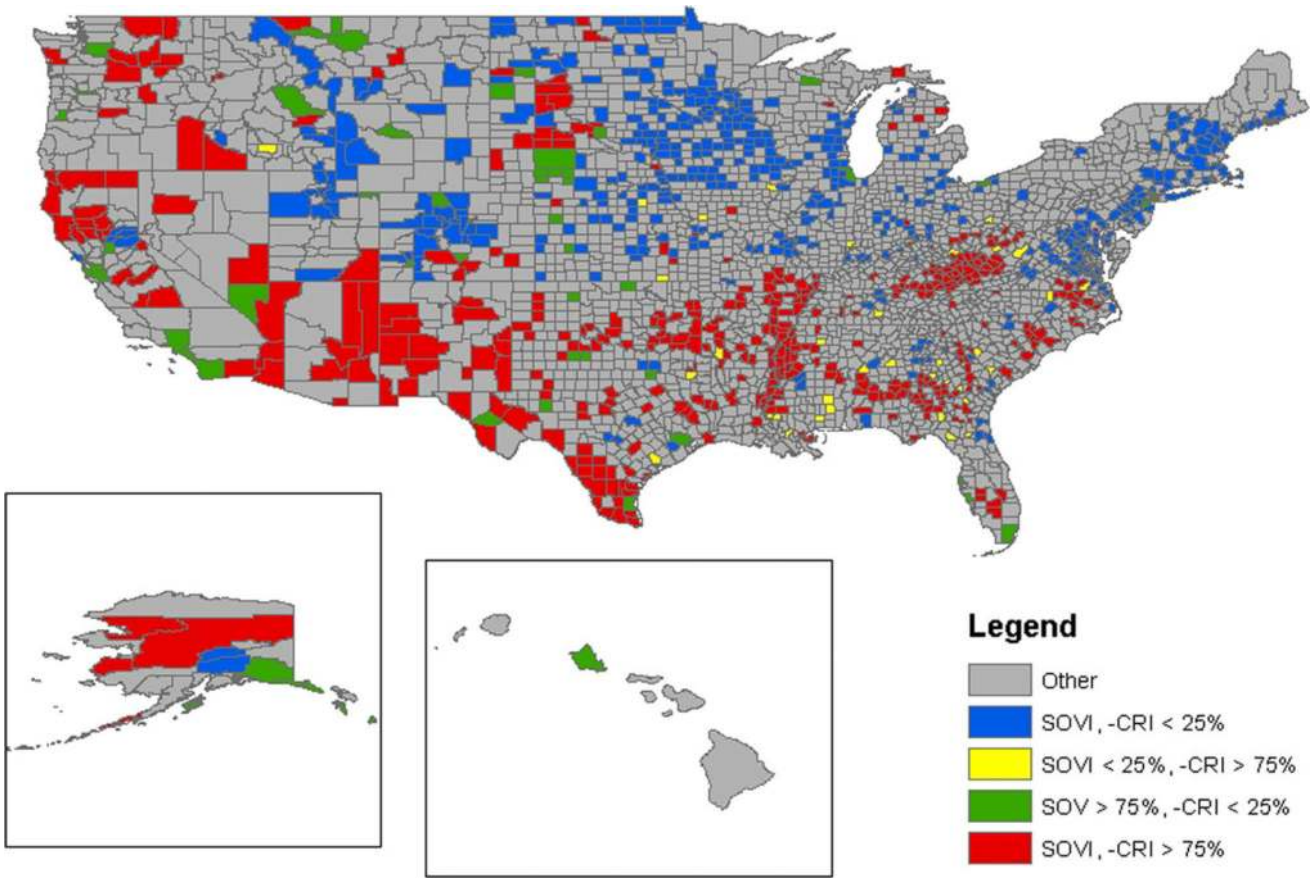


**Fig. 5.**
Map of the association between SoVI and negative CRI

## Table 1

SoVI factor loading of 30 variables related to vulnerability

| Factor | Variable name | Variable meaning | Factor loading |
|---|---|---|---|
| Factor 1 (−) | QASIAN | Percent Asian | 0.53814 |
| | QRICH200 K | Percent of households earning >$200,000 annually | 0.81709 |
| | PERCAP | Per capita income | 0.7493 |
| | MDHSEVL | Median house value | 0.82314 |
| | MDGRENT | Median rent | 0.81319 |
| Factor 2 (+) | QBLACK | Percent black | 0.88401 |
| | QFAM | Percent of children living in married couple families | −0.85721 |
| | QPOVTY | Percent poverty | 0.63115 |
| | QFHH | Percent female headed household | 0.89318 |
| | QED12LES | Percent with <12th grade education | 0.52361 |
| | QNOAUTO | Percent of housing units with no car | 0.68889 |
| Factor 3 (+) | QAGEDEP | Percent of population under 5 years or 65 and over | 0.86875 |
| | MEDAGE | Median age | 0.83234 |
| | QSSBEN | Percent of households receiving social security | 0.79659 |
| | PPUNIT | People per unit | −0.59688 |
| | QFEMLBR | Percent female participation in labor force | −0.4954 |
| Factor 4 (+) | QHISP | Percent hispanic | 0.88465 |
| | QESL | Percent speaking english as a second language with limited english proficiency | 0.86839 |
| | QNOHLTH | Percent of population without health insurance | 0.70393 |
| Factor 5 (+) | POPDENS | Population density | 0.50872 |
| | PCTURBAN00 | Percent urban population | 0.66189 |
| | QRENTER | Percent renters | 0.68855 |
| | QMOHO | Percent mobile homes | −0.46964 |
| Factor 6 (−) | NRRESPC | Percent of population 65 and over in group quarters | 0.68976 |
| | HOSPTPC | Hospitals per capita | 0.61155 |
| | QSPNEEDS | Percent of population with a disability | −0.37735 |
| Factor 7 (+) | QCVLUN | Percent civilian unemployment | 0.68124 |
| | QEXTRCT | Percent employed in extractive industry | 0.45621 |
| | QSERV | Percent employment in service industry | −0.61815 |
| Factor 8 (+) | QNATAM | Percent native american | 0.93623 |

**Table 2**

National and regional means and standard deviations

| | National | | Midwest | | Northeast | | South | | West | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***M*** | ***SD*** | ***M*** | ***SD*** | ***M*** | ***SD*** | ***M*** | ***SD*** | ***M*** | ***SD*** |
| SoVI | 0.36 | 4.02 | −0.89 | 3.61 | −0.27 | 6.06 | 0.82 | 3.02 | 2.16 | 5.37 |
| CRI | −0.001 | 0.77 | 0.28 | 0.60 | 0.53 | 0.67 | −0.35 | 0.71 | 0.20 | 0.88 |