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Measuring Community Vulnerability to Natural and Anthropogenic Hazards: The Centers for Disease Control and Prevention's Social Vulnerability Index

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Introduction

Until recent decades, the focus of disaster management remained largely on attributes of the physical world, primarily risk assessments of the threat of natural and anthropogenic hazards to the built environment. The concept of social vulnerability within a disaster management context received increasing attention when researchers recognized that a more complete assessment of risk must also include the socioeconomic and demographic factors that affect community resilience (Flanagan, Gregory, Hallisey, Heitgerd, & Lewis, 2011; Juntunen, 2005).

All regions of the U.S. have experienced natural and human-caused disasters. The hazards that precipitate these disasters will continue to occur in the future. Hazards can be large scale, such as hurricanes and earthquakes, or they can be relatively localized in extent, such as tornadoes or chemical spills. Although hazard events might be relatively benign, they can culminate in disaster—severe injuries, emotional distress, loss of life, and property damage—to the extent of destroying entire communities. In both the short- and long-term future, disasters can have devastating health, social, and economic consequences for affected areas and their inhabitants.

Our work draws on research that examines vulnerability as a social condition or as a measure of the resilience of population groups when confronted by disaster (Cutter, Boruff, & Shirley, 2003). Social vulnerability is defined in terms of the characteristics of a person or community that affect their capacity to anticipate, confront, repair, and recover from the effects of a disaster. Some examples of factors that might affect a person's social vulnerability include socioeconomic status, household composition, minority status, and vehicle access. The social vulnerability literature reveals that populations living in a disaster-stricken area are not affected equally (Bolin, 2006). Evidence indicates that the poor are more vulnerable at all stages of a catastrophic event, as are racial and ethnic minorities, children, elderly, and disabled people (Morrow, 1999). Socially vulnerable communities are more likely to experience higher rates of mortality, morbidity, and property destruction, and

are less likely to fully recover in the wake of a disaster compared to communities that are less socially vulnerable (Juntunen, 2005).

Social Vulnerability Index Database

Pursuant to the Pandemic and All-Hazards Preparedness Act of 2006 that cited public health and medical preparedness and response capabilities as a critical national need, the Geospatial Research, Analysis, and Services Program (GRASP) at Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry created a Social Vulnerability Index (SVI) database and mapping tool designed to assist state, local, and tribal disaster management officials in identifying the locations of their most socially vulnerable populations (Agency for Toxic Substances and Disease Registry [ATSDR], 2018).

To date, GRASP has produced national social vulnerability indices for years 2000, 2010, 2014, and 2016. We constructed the index at census tract level, a geographic scale commonly used to analyze community data for policy and planning in government and public health (Krieger, 2006). In response to the demand from health department officials, we also provide SVI databases at county level.

Each SVI database comprises 15 census variables, except for the 2010 index as the U.S. Census Bureau did not collect disability data that year (ATSDR, 2018). Each of the census variables was ranked from highest to lowest vulnerability across all census tracts in the nation with a nonzero population. A percentile rank was calculated for each census tract for each variable. The variables were then grouped among four themes (Figure 1). A tract-level percentile rank was also calculated for each of the four themes. Finally, an overall percentile rank for each tract as the sum of all variable rankings was calculated. This process of percentile ranking was then repeated for the individual states.

In a second approach to identifying social vulnerability, we flagged each tract having a variable with a percentile rank ≥ 90 and summed the tract flags to produce counts for each theme and overall. This approach identifies tracts having a high percentile ranking on one or more variables for which overall vulnerability is masked by other variables having low percentiles.

The mapping of these data (Figure 2) reveals geographic patterns of potential vulnerability to disaster that can be used in all phases of the disaster cycle: preparedness, response, recovery, and mitigation (Morrow, 1999). The SVI database can assist public health officials to better prepare for and respond to emergency meteorological and geological events, disease outbreaks, and human-caused incidents.

SVI Database Use and Validation

The SVI database is used in disaster management by several U.S. state and local governments, as well as several private sector organizations. Examples of studies using the SVI database include

- mapping fire outbreaks and vulnerability metrics to target aid during emergencies (Lue & Wilson, 2017);
- hazard mitigation planning studies (Horney et al., 2017; Horney, Simon, Grabich, & Berke, 2015);
- adult physical inactivity (An & Xiang, 2015; Gay, Robb, Benson, & White, 2016); and
- use of the SVI database, or portions of it, to assess social vulnerability and physical hazards (e.g., sea level rise, flooding, tornadoes, volcanic risk, house fires), hazard awareness, rural/urban differences, migrant and refugee populations, and health status (e.g., youth fitness).

An ongoing GRASP validation effort exists to further clarify the scope and utility of the SVI database. Here we highlight several projects used in our validation effort. A post-Katrina recovery study in New Orleans, Louisiana, found that heavily damaged communities were slow to recover regardless of neighborhood characteristics. Communities with socially vulnerable populations, however, were also slow to recover even without heavy flood damage, and vulnerable communities experiencing heavy damage were slowest to recover (Flanagan et al., 2011). A study in Georgia showed significant spatial clustering and increased rates of extreme heat-related mortality and emergency department visits in areas of high social vulnerability (Adams et al., 2016). Following a series of hurricanes in 2017, the SVI database was applied to media reported mortality data to better understand hurricane-related deaths (Lavery, 2017). A study coupling data from the SVI database with health and environmental data reported the database as a significant predictor of asthma emergency department rates with the strength of prediction varying across counties in the study area (Kolling, Wilt, Berens, Stros-nider, & Devine, 2017).

The SVI database has been cited over 100 times in the academic literature (<http://researchgate.net/publication/274439003>). Finally, an independent effort to validate several social vulnerability indices as guides to disaster preparation, recovery, and adaptation finds that the SVI database compares well to other indices, especially with regard to explaining property losses and fatalities (Bak-kensen, Fox-Lent, Read, & Linkov, 2017).

Conclusion

Opportunities for expanding the application of the SVI database could include disaster and non-disaster related uses. The database can be used to examine correlations between aggregate health disparities in communities and potential social barriers to access to care. Forthcoming analyses at the Centers for Disease Control and Prevention aim to identify potential interactions between social vulnerability and environmental burdens faced by communities, including air, water, and soil contamination. Lastly, we believe the SVI database can be productively applied to a myriad of other hazards, threats, and social or health outcomes that communities might encounter in the coming years.

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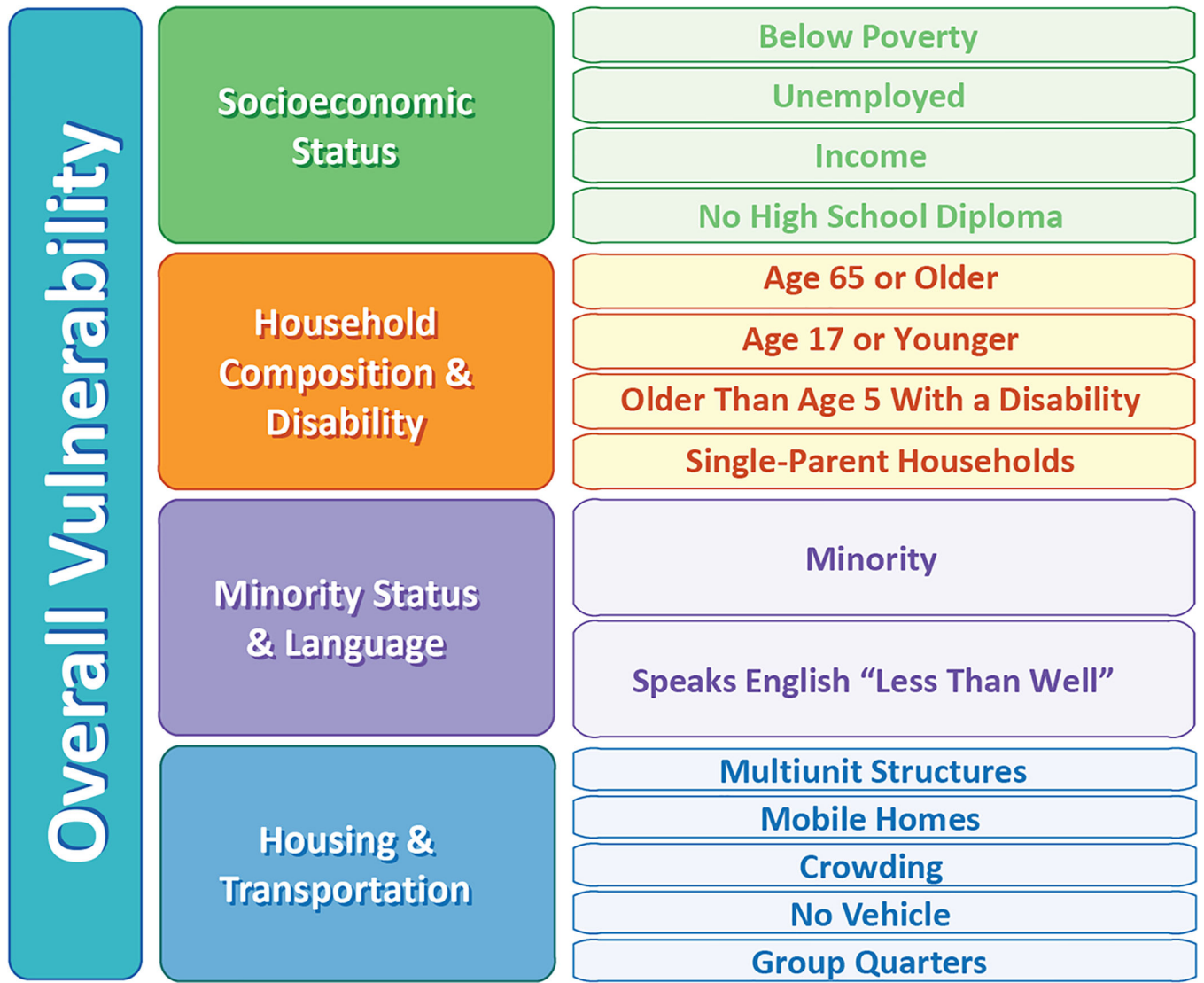


FIGURE 1. Variables and Themes Included in the Social Vulnerability Index Databases

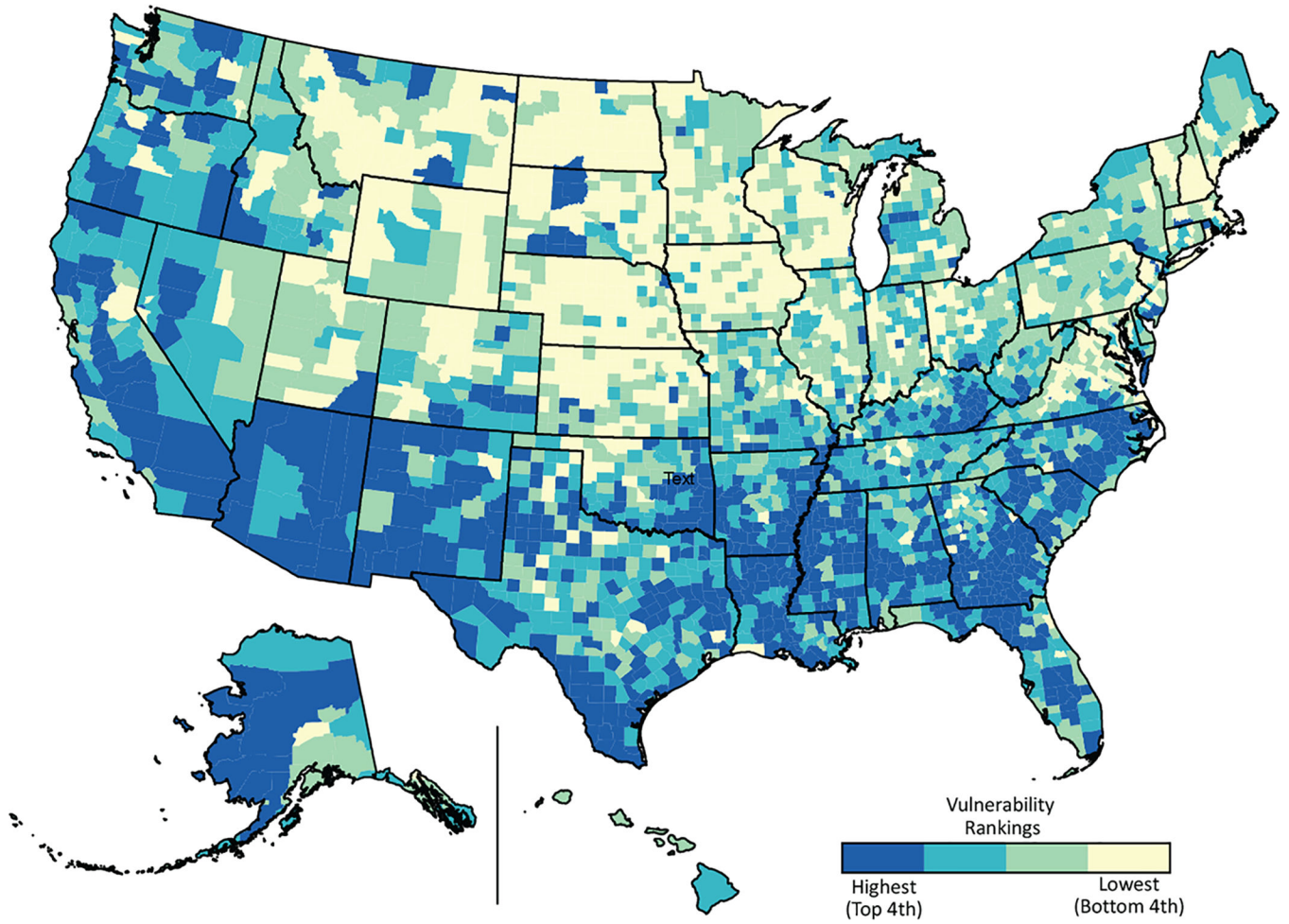


FIGURE 2.
Overall U.S. Vulnerability at County Level as Identified in the Social Vulnerability Index