Disaster Resilience Indicators for Benchmarking Baseline Conditions

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Abstract

There is considerable federal interest in disaster resilience as a mechanism for mitigating the impacts to local communities, yet the identification of metrics and standards for measuring resilience remain a challenge. This paper provides a methodology and a set of indicators for measuring baseline characteristics of communities that foster resilience. By establishing baseline conditions, it becomes possible to monitor changes in resilience over time in particular places and to compare one place to another. We apply our methodology to counties within the Southeastern United States as a proof of concept. The results show that spatial variations in disaster resilience exist and are especially evident in the rural/urban divide, where metropolitan areas have higher levels of resilience than rural counties. However, the individual drivers of the disaster resilience (or lack thereof)—social, economic, institutional, infrastructure, and community capacities—vary widely.

Introduction

Within federal circles, there continues to be considerable interest in the subject of disaster resilience. The Subcommittee on Disaster Reduction's (SDR) Grand Challenges report (SDR 2005), which provided a blueprint for characterizing and fostering disaster resilient communities stimulated the initial interest in disaster resilience. Now with the formal establishment of the Office of Resilience within the National Security Council in the White House, the policy community has adopted resilience as one of the guiding principles for making the nation safer. The policy goal is clear and pragmatic—if communities can increase their resilience then they are in a much better position to withstand adversity and to recover more quickly than would be the case if there were few or no investments in building community resilience.

Interestingly, the policy community is slightly ahead of the research community in pushing resilience as a means of mitigating disaster impacts. Lingering concerns from the research community focus on disagreements as to the definition of resilience, whether resilience is an outcome or a process, what type of resilience is being addressed (economic systems, infrastructure systems, ecological systems, or community systems), and which policy realm (counterterrorism; climate change; emergency management; long-term disaster recovery; environmental restoration) it should target. Some of these issues have been discussed elsewhere (Cutter 2008a, b; Kahan et al. 2009; Klein et al. 2003; Manyena 2006; Norris et al. 2008; Rose 2007; also see the CARRI research reports at www.resilientus.org/publications).

This article provides a methodology and a set of indicators to measure the present conditions influencing disaster resilience within communities. It then applies this methodology to the Southeastern U.S. One key question drives the analysis: How can we identify changes (either positive or negative) in community resilience to disasters if we do not first have an understanding of the existing conditions? The resilience indicators proposed in this paper serve as the baseline set of conditions, from which to measure the effectiveness of programs, policies, and interventions specifically designed to improve disaster resilience. While not exhaustive, this set of baseline indicators provides one of the first empirically based efforts to benchmark the pre-existing conditions that foster community resilience.

Divergent Views on Community Resilience

The application of the resilience concept to natural hazards was initially the focal argument in the assessment of natural hazards (Mileti 1999), which suggested that resilience was the ability of a community to recover by means of its own

resources. Norris et al. (2008) also focus on community resilience and view it as a process linking the myriad of adaptive capacities (such as social capital and economic development) to responses and changes after adverse events. Here resilience is as a set of capacities that can be fostered through interventions and policies, which in turn help build and enhance a community's ability to respond and recover from disasters.

A very different conceptualization of disaster resilience comes from the engineering sciences, with an emphasis on buildings and critical infrastructure resilience. Using seismic risks as the exemplar, Bruneau et al. (2003) proposed a resilience framework with an emphasis on structural mitigation, especially the engineered systems concepts of robustness, redundancy, resourcefulness, and rapidity. More recent research on resilience from a homeland security perspective (primarily protecting critical infrastructure from terrorism) (Kahan et al. 2009) also focuses on critical infrastructure resilience assuming that resilience is an outcome measure with an end goal of limiting damage to infrastructure (termed resistance); mitigating the consequences (called absorption); and recovery to the pre-event state (termed restoration). While perhaps useful for counterterrorism and protection of critical infrastructure, this operational framework ignores the dynamic social nature of communities and the process of enhancing and fostering resilience within and between communities.

Composite Indicators for Disaster Resilience

Not only is it vital to evaluate and benchmark the baseline conditions that lead to community resilience, but it is equally important to measure the factors contributing to adverse impacts and the diminished capacity of a community to respond to and rebound from an event (Cutter et al. 2008a). Just as companies have identified areas of opportunity and benchmarked their performance against industry standards, governments are finding it useful to evaluate the performance of communities in terms of their comparative resilience. While the latter is partially to attract public interest in disaster loss reduction, it also provides metrics to set priorities, measure progress, and aid in decision-making processes. Composite indicators (often referred to as indices) are useful tools to accomplish this task.

We use the term "composite indicator" to designate a manipulation of individual variables to produce an aggregate measure of disaster resilience. An indicator is a quantitative or qualitative measure derived from observed facts that simplify and communicate the reality of a complex situation (Freudenberg 2003). Indicators reveal the relative position of the phenomena being measured and when evaluated over time, can illustrate the magnitude of change (a little or a lot) as well as direction of change (up or down; increasing or decreasing). A composite

indicator is the mathematical combination of individual variables or thematic sets of variables that represent different dimensions of a concept that cannot be fully captured by any individual indicator alone (Nardo et al. 2008).

Composite indicators are increasingly recognized as useful tools for policy making and public communication because they convey information that may be utilized as performance measures (Saisana and Cartwright 2007). Numerous approaches for measuring composite indicators at both global and local scales have emerged. Many of these are central to the environmental hazards and natural disasters community as they were developed to capture a society's vulnerability to social and/or environmental change. Among these are metrics created to assess the susceptibility of small states to fluctuations within international economies (Briguglio 1995; Easter 1999) and indicators designed to measure national well-being (Millennium Change Corporation (MCC) 2007; Neumayer 2001; Prescott-Allen 2001).

Also significant are composite indicators of social vulnerability to natural or technological hazards. Cutter et al.'s Social Vulnerability Index (SoVI) is perhaps the most well-known and widespread example (Cutter et al. 2003). Additional indices that focus explicitly on aspects of social vulnerability include the Prevalent Vulnerability Index (Cardona 2005), the Index of Social Vulnerability to Climate Change for Africa (Vincent 2004), the Disaster Risk Index (United Nations Development Program 2004), and the Predictive Indicator of Vulnerability (Adger et al. 2004).

Similar metrics provide global assessments of quality of life and sustainable development. These include the Human Development Index (United Nations Development Program 1990, 2005) and the Environmental Sustainability Index (Esty et al. 2005). Several indices have also been constructed to evaluate the vulnerability of natural environments (Kaly et al. 2003; Kaly et al. 2004), ecological health and environmental sustainability (Heinz Center 2008; National Research Council 2000; Organization for Economic Cooperation and Development (OECD) 2001) at a sub-national level. Lastly, composite indicators have been utilized to determine the physical and social vulnerability of coastal environments to sea level rise and its impacts (Boruff et al. 2005; Gommes et al. 1998; Pethick and Crooks 2000).

Study Area Description

This study focuses on counties within the U.S. Federal Emergency Management Agency's (FEMA) Region IV (Figure 1). Region IV serves the southeastern states

Figure 1: Study area

of Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. The impacts of natural disasters within this region are widespread and vary extensively. Abundant rainfall and frequent thunderstorms mean that flooding is a common problem for the region. Since 2000, for instance, there have been more than 900 flood events in the state of Mississippi alone, resulting in $410 million in property damage (Oxfam America 2009). The region is also vulnerable to hurricanes that bring damaging winds, coastal and inland flooding, catastrophic storm surge, and coastal erosion. Most of North America's well-known and most destructive hurricanes have affected this region--Hurricane Hugo in 1989, Hurricane Andrew in 1992, Hurricane Ivan in 2004, and Hurricane Katrina in 2005, the costliest disaster in U.S. history. Natural events such as tornados, earthquakes, drought, and sea level rise also threaten the region.

Historically, the states that make up FEMA Region IV have been at the periphery of the U.S. economy, yet in recent decades, the region has become one of significant growth with massive transformations in urbanization and industrialization, in cultural and societal viewpoints, in agriculture, and in politics (Wheeler 1999). The region was predominantly rural, with relatively few major cities. This has changed over the past several decades and cities such as Atlanta, Miami, Charlotte, Birmingham, Nashville, and Memphis continue to grow in national and international importance. Many rural and peripheral areas remain poor, however, benefitting little from the new prosperity enjoyed by the burgeoning metropolitan areas. These counties continue to have a high degree of racial inequality and health disparities, where education and job skills are limited, where the age composition of the existing population is elderly, and where a high rate of outmigration exists.

Data and Methods

Theoretical framework for measuring disaster resilience

The literature on composite indicators is vast, and contains many methodological approaches for index construction and validation. Most of the literature highlights the need for a process of indicator construction that entails a number of specific steps (Freudenberg 2003; Nardo et al. 2008). The first step involves the development or application of a theoretical framework to provide the basis for variable selection, weighting, and aggregation. This paper utilizes the inherent resilience portion of the disaster resilience of place (DROP) model (Cutter et al. 2008b) as its conceptual basis. The DROP model presented the relationship between vulnerability and resilience in a manner that is theoretically grounded and amenable to empirical testing. Furthermore, the DROP framework explicitly focused on antecedent conditions, specifically those related to inherent resilience. Antecedent conditions are the product of place specific, multi-scale processes that occur within and between natural systems, the built environment, and social systems. Most of the scientific literature points to resilience within natural systems (*e.g.,* keeping wetlands intact or controlling development), yet the resilience of social and organizational systems is equally significant. Disaster impacts may be reduced through improved social and organizational factors such as increased wealth, the widespread provision of disaster insurance, the improvement of social networks, increased community engagement and participation, and the local understanding of risk (Cutter et al. 2008a), as well as through improvements in resilience within natural systems.

Variable selection

Another crucial step in the creation of composite indicators is the identification of variables that are relevant, robust, and representative, since the strengths and weaknesses of composite indicators are based on the quality of the variables chosen. Criteria for assuring the quality of variables are widespread within the indicators literature, yet to date there is no single set of established indicators or frameworks for quantifying disaster resilience. However, there is consensus within the research community that resilience is a multifaceted concept, which includes social, economic, institutional, infrastructural, ecological, and community elements (Bruneau et al. 2003; Cutter et al. 2008a, b; Gunderson 2009; NRC 2010; Norris et al. 2008). Based on these findings, our index comprises these subcomponents that were then further defined for analytic and comparative purposes. Since it is often difficult to measure resilience in absolute terms, we use a comparative approach and employ variables as proxies for resilience (Cutter et al. 2008b; Schneiderbauer and Ehrlich 2006). The variable selection had two considerations: 1) justification based on the extant literature on its relevance to resilience; and 2) availability of consistent quality data from national data sources.

We purposefully excluded ecological (or natural systems) resilience in this present formulation. This is primarily due to data inconsistency and relevancy when developing proxies for ecological systems resilience for large and diverse study areas. For example, the inclusion of variables (in coastal areas) that account for the prevalence or loss of wetlands and dunes is essential because they provide buffers against storm surges. However, the use of such variables in regions far removed from the coast or where wetlands and dunes are non-existent would improperly skew results by implying a reduction in disaster resilience based on the lack of these particular attributes.

Before the construction of the sub-indices could occur, a third step toward creating a suitable composite index took place. All raw data values were transformed into comparable scales utilizing percentages, per capita, and density functions. These forms of standardization were essential to avoid problems inherent when mixing measurement units since our variables were delineated in a number of statistical units, ranges, and scales. The variables were then analyzed for significantly high correlations between individual variables and when such high correlations (e.g. Pearson's R>0.70) were found, the variable was eliminated from further consideration. Additionally, the internal consistency (reliability) of the composite indicators was assessed utilizing a Chronbach's Alpha Reliability/Item analysis. We coupled a correlation analysis with a test for internal consistency to decide whether the nested structure of the index was well defined from a statistical perspective and if the available sub-indicators were sufficient and appropriate to describe the disaster resilience phenomenon from a theoretical

Table 1: Variables used to construct disaster resilience index by subcomponent

Category	Variable	Effect on Resilience	Justification	Data Source
Social Resilience				
Educational equity	Ratio of the pct. population with college education to the pct. population with no high school diploma	Negative	Norris et al. 2008 Morrow 2008	U.S. Census 2000
Age	Percent non-elderly population	Positive	Morrow 2008	U.S. Census 2000
Transportation access	Percent population with a vehicle	Positive	Tierney 2009	U.S. Census 2000
Communication capacity	Percent population with a telephone	Positive	Colten et al. 2008	U.S. Census 2000
Language competency	Percent population not speaking English as a second language	Positive	Morrow 2008	U.S. Census 2000
Special needs	Percent population without a sensory, physical, or mental disability	Positive	Heinz Center 2002	U.S. Census 2000
Health coverage	Percent population with health insurance coverage	Positive	Heinz Center 2002	U.S. Census 2000
Economic Resilience				
Housing capital	Percent homeownership	Positive	Norris et al. 2008 Cutter et al. 2008a	U.S. Census2000
Employment	Percent employed	Positive	Tierney et al. 2001	U.S. Census 2000
Income and equality	GINI coefficient	Positive	Norris et al. 2008	Computed from U.S. Census 2000
Single sector employment dependence	Percent population not employed in farming, fishing, forestry, and extractive industries	Positive	Berke & Campanella 2006 Adger 2000	U.S. Census 2000
Employment	Percent female labor force participation	Positive	NRC 2006	U.S. Census 2000
Business size	Ratio of large to small businesses	Positive	Norris et al. 2008	County Business Patterns (NAICS) 2006
Health Access	Number of physicians per 10,000 population	Positive	Norris et al. 2008	U.S. Census 2000
Institutional Resilience				
Mitigation	Percent population covered by a recent hazard mitigation plan	Positive	Burby et al. 2000 Godschalk 2007	FEMA.gov
Flood coverage	Percent housing units covered by NFIP policies	Positive	Burby et al. 2000	bsa.nfipstat.com
Municipal services	Percent municipal expenditures for fire, police, and EMS	Positive	Sylves 2007	USA Counties 2000
Mitigation	Percent population participating in Community Rating System for Flood (CRS)	Positive	Godshalk 2003	FEMA.gov
Political fragmentation	Number of governments and special districts	Negative	Norris et al. 2008	U.S. Census 2002
Previous disaster experience	Number of paid disaster declarations	Positive	Cutter et al. 2008a	FEMA.gov
Mitigation and social connectivity	Percent population covered by Citizen Corps programs	Positive	Godshalk 2003	citizen.corps.gov
Mitigation	Percent population in Storm Ready communities	Positive	Godshalk 2003	stormready.noaa.gov
Infrastructure Resilience				
Housing type	Percent housing units that are not mobile homes	Positive	Cutter et al. 2003	U.S. Census 2000
Shelter capacity	Percent vacant rental units	Positive	Tierney 2009	U.S. Census 2000
Medical capacity	Number of hospital beds per 10,000 population	Positive	Auf de Heide and Scanlon 2007	American Hospital Directory www.ahd.com
Access/ evacuation potential	Principle arterial miles per square mile	Positive	NRC 2006	GIS derived from National Atlas.gov
Housing age	Percent housing units not built before 1970 and after 1994	Positive	Mileti 1999	City and County Databook 2007
Sheltering needs	Number of hotels/motels per square mile	Positive	Tierney 2009	County Business Patterns (NAICS) 2006
Recovery	Number of public schools per square mile	Positive	Ronan and Johnston 2005	Gnis.usgs.gov
Community Capital				
Place attachment	Net international migration	Negative	Morrow 2008	census.gov
Place attachment	Percent population born in a state that still resides in that state	Positive	Vale & Campanella 2005	U.S. Census 2000
Political engagement	Percent voter participation in the 2004 election	Positive	Morrow 2008	City and County Databook 2007
Social capital-religion	Number of religious adherents per 10,000 population	Positive	Morrow 2008 Murphy 2007	Assn. of Religion Data Archives
Social capital – civic involvement	Number of civic organizations per 10,000 population	Positive	Morrow 2008 Murphy 2007	County Business Patterns (NAICS) 2006
Social capital – advocacy	Number of social advocacy organizations per 10,000 population	Positive	Murphy 2007	County Business Patterns (NAICS) 2006
Innovation	Percent population employed in creative class occupations	Positive	Norris et al. 2008	USDA Economic Research Service ers.usda.gov

perspective. More than 50 variables were originally collected for this analysis. However, after removing all highly correlated variables and achieving a level of internal consistency that is generally accepted within the literature (Chronbach's Alpha = 0.700) (Nardo et al. 2008), thirty-six variables were employed in our analysis. Each of the subcomponents contains seven to eight variables, culled from publically available data sources (Table 1).

Components of disaster resilience

Our first subcomponent, social resilience, captured the differential social capacity within and between communities. Linking demographic attributes to social capacity (see Table 1) suggests that communities with higher levels of educational equality, and those with fewer elderly, disabled residents, and non-native English speaking residents likely exhibit greater resilience than places without these characteristics. Similarly, communities that have high percentages of inhabitants with vehicle access, telephone access, and health insurance also may demonstrate higher levels of disaster resilience.

Economic resilience, the second subcomponent measures the economic vitality of communities including housing capital, equitable incomes, employment, business size, and physician access. Variables within this component include percent employment, percent homeownership, business size, female labor force participation, and a proxy for single sector employment dependence. This variable provides a measure whether the local economic base is diversified (more resilient) or largely based on a single sector such as agriculture or fishing, which makes the community less resilient. These indicators allow the examination of links that enhance or diminish economic stability at the community level, particularly the stability of livelihoods. Dependency on a narrow range of natural resources is an example of an economic factor directly related to the stability of livelihoods. A reduction in resilience occurs, for example, due to the boom and bust nature of single sector markets (Adger 2000) and due to the threat of losses that may occur in a single sector economy (such as fishing or agriculture) from an extreme event.

From a natural hazards perspective our third component, institutional resilience, contains characteristics related to mitigation, planning, and prior disaster experience (Table 1). Here, resilience is affected by the capacity of communities to reduce risk, to engage local residents in mitigation, to create organizational linkages, and to enhance and protect the social systems within a community (Norris et al. 2008). Federal, state, and local governments within the U.S. are slowly beginning to comprehend that the long term benefits of planning and mitigation are important tools for increasing resilience and reducing losses

following natural disasters since no two areas are alike in their capacities to sustain and recover from future disasters (Burby et al. 2000). Institutional resilience variables include the percentage of the population covered by a recent hazard mitigation plan, the percent of the population residing in Storm Ready communities, and the number of governments and special districts per county (a measure of political fragmentation).

The fourth subcomponent, infrastructural resilience, is mainly an appraisal of community response and recovery capacity (e.g. sheltering, vacant rental housing units, and healthcare facilities). These indicators also provide an overall assessment of the amount of private property that may be particularly vulnerable to sustaining damage and likely economic losses. Vulnerable infrastructure includes mobile homes that are particularly susceptible to catastrophic loss during an event, and houses built prior to the enactment of mandatory building codes. Critical infrastructure variables such as the amount principle arterial miles within an area are also included since this type of infrastructure not only provides a means for pre-event evacuations, but also acts as conduits for vital supplies, post-disaster. A coastal community only accessible by a two-lane bridge may be more vulnerable and less resilient than one with multiple ingress and egress routes. Such a community would remain isolated and dependent upon costly airlifts and boatlifts for supplies until an alternate route or temporary bridge was constructed.

The final sub-index, community capital, captures the relationships that exist between individuals and their larger neighborhoods and communities. The community capital sub-index embodies what many refer to as social capital. We attempt to capture three key dimensions of social capital: sense of community, place attachment, and citizen participation. We do this through proxies such as the number of religious adherents (per 10,000 people), the number of civic and social advocacy organizations (per 10,000 people), and the percentage of the population employed in creative class occupations (knowledge-based workers, science, engineering, arts, design, and the media) (Florida 2002), which is used as a surrogate for social innovation. A sense of community is directly related to bonding and is characterized by high concern for community issues, respect for and service to others, and a sense of connection (Goodman et al. 1998; Norris et al. 2008). Place attachment refers to one's sense of community and often underlies citizens' efforts to revitalize a community (Perkins et al. 2002), and citizen participation is the engagement of community members in formal organizations, including religious congregations and self-help groups.

Data aggregation and weighting

Once selected, the variables were normalized using a Min-Max rescaling scheme to create a set of indicators on a similar measurement scale. Min-Max rescaling is a method in which each variable is decomposed into an identical range between zero and one (a score of 0 being the worst rank for a specific indicator and a score of 1 being the best). All other values were scaled in between the minimum and maximum values. This scaling procedure subtracted the minimum value and divided by the range of the indicator values. For some variables in which high values corresponded to low levels of resilience, our rescaling process also involved reversing the order of their contribution to the overall resilience index before the rescaling process could take place. This was done by taking the inverse of the observation and then rescaling the variable, so that zero equals low resilience and one represents high resilience. Our net international migration variable provides an example of this form of inverse scaling since a high net international migration reduces resilience. When scaled by taking the inverse of the value, the highest value for international migration within the dataset receives a score of zero and the lowest value for that variable receives a score of one. In other words, communities with a large influx of recent international immigrants are less resilient than those without.

      After normalizing the variables for cross county comparisons, we employed a method of aggregation in which our final disaster resilience score represents the summation of the equally weighted average sub-index scores. In other words, the variable scores in each sub-index were averaged to reduce the influence of the different number of variables in each sub-index. These arithmetic mean scores resulted in a sub-index score for each county, and then these sub-index scores were summed to produce a final composite resilience score. Since there are five sub-indices, scores range between zero and five (0 being the least and 5 being the most resilient). We chose an equally weighted index at both the sub-index and composite indicator level for two reasons. First, this simple method of aggregation is transparent and easy to understand, a criteria we deemed important for potential users. Second, we find no theoretical or practical justification for the differential allocation of importance across indicators. While methods exist for determining weights that are subjective or data reliant, such weighting schemes do not always reflect the priorities of decision makers (Esty et al. 2005).

Results

The disaster resilience scores provide a comparative assessment of community resilience for the 736 counties within FEMA Region IV. We provide two approaches to the results. The first is a spatial assessment and the second provides an empirical ranking of the most and least resilient counties. Figure 2 is a spatial representation of the disaster resilience within the study region. Our scores, mapped as standard deviations from the mean, highlight those counties that are ranking exceptionally well or poor in terms of their disaster resilience. Counties symbolized in dark blue are highly resilient whereas counties symbolized in red are the least resilient.
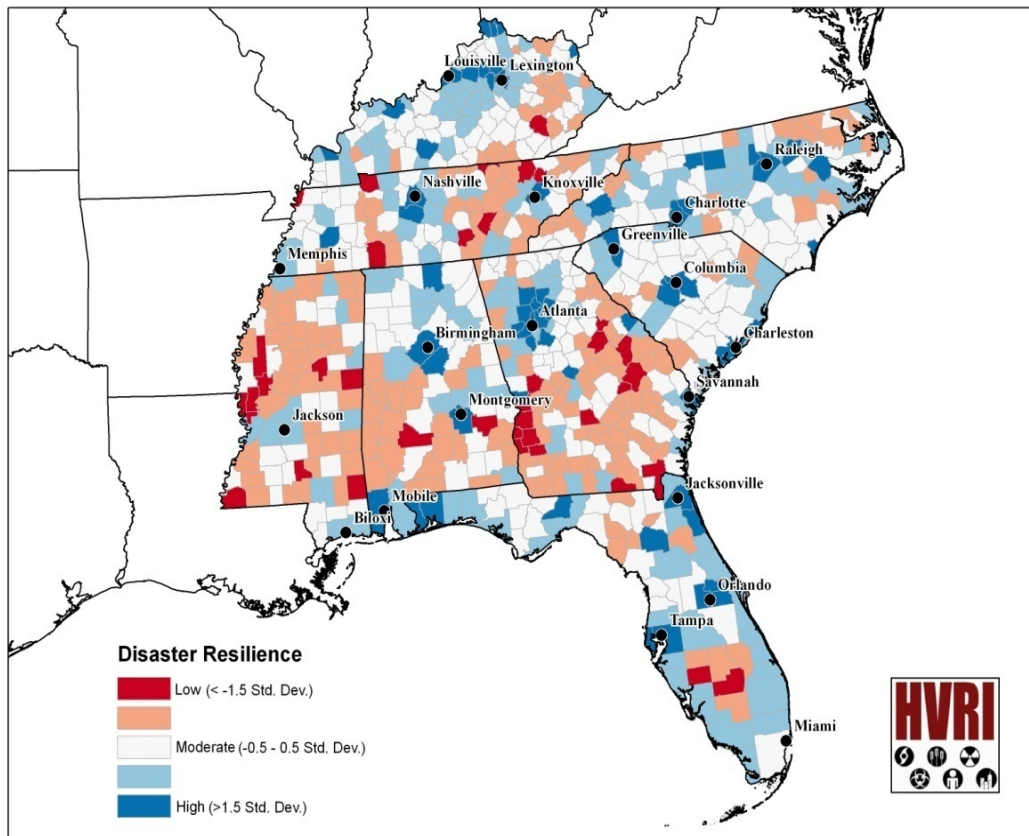

Figure 2: Spatial distribution of disaster resilience for FEMA region IV

When visualized in the form of a regional map, geographic variations are evident. The results illustrate an urban-rural bias, where metropolitan areas such as Louisville, Nashville, Atlanta, Birmingham, Charlotte, and Tampa-St. Petersburg show comparatively high levels of resilience. The notable exception to this pattern is the absence of Miami, which shows only moderate levels of resilience. The rural counties within our analysis typically demonstrate moderate to low levels of resilience. This pattern is not only evident across the entire Southeast, but is also present within each state individually.

To determine some of the underlying driving factors that contribute to this trend, we delineated the social, economic, institutional, infrastructure, and community capital components of the disaster resilience index (Figure 3). Several spatial patterns are noteworthy. First, counties that rank high in social resilience (Figure 3a) tend to cluster within or very near to medium/large metropolitan areas, with the exceptions of central and south Florida cities. The economic resilience component (Figure 3b) displays a slightly different distribution with higher levels of economic resilience concentrated in inland counties (Ft. Lauderdale and Jacksonville are exceptions), particularly along the I-85 and I-20 corridors stretching from Birmingham to Raleigh. The economic resilience found in the capital cities (Jackson, MS) and in major industrial and tourist hubs (Memphis, Nashville) are clear as well. The institutional component of disaster resilience (Figure 3c) diverges from the urban-rural pattern, however. Here, nearly all counties within Florida are highly resilient based on this measure, which reflects prior disaster experience and the adoption of mitigation measures such as flood insurance or community participation in Storm Ready programs. Most of the coastal counties in the region also display moderate to high levels of institutional resilience. Also notable is the low level of institutional resilience in the Appalachian region of western Tennessee.
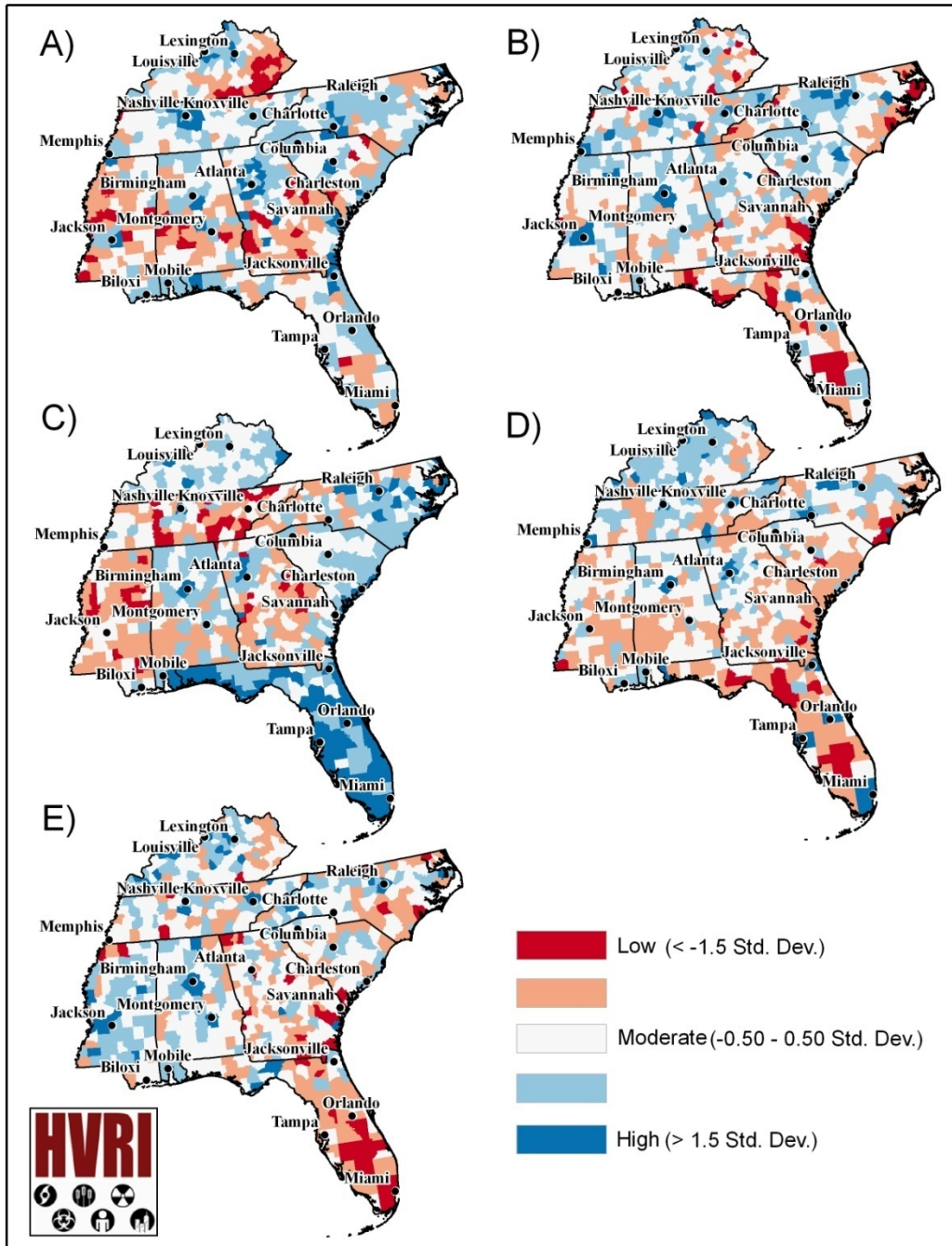
Figure 3: Subcomponents of disaster resilience for FEMA Region IV: A) social resilience, B) economic resilience, C) institutional resilience, D) infrastructure resilience, E) community capital

A different pattern emerges with the infrastructure component (Figure 3d) which shows a north-south bias in which a large percentage of counties within Kentucky, Tennessee, and North Carolina have moderate to high levels of infrastructural resilience. This is partially the result fewer mobile homes, and greater medical and sheltering capacity. It is also a function of the availability of evacuation routes (highways). Finally, the community capital component shows a slight western bias within the region. For example, a large number of counties in central and western Kentucky have high levels of community capital (Figure 3e), as do the western portions of Tennessee and most of Mississippi. Much of this is attributed to place attachments and the role of civic organizations, social advocacy organization, and religious adherents within these counties.

Table 2 provides a ranking of the 10 most and least resilient counties. The places with the highest disaster resilience are in four different states and include counties within the metropolitan statistical areas of Louisville, Birmingham, Nashville, and Tampa-St. Petersburg (Table 2). The resilience scores within the counties ranking highest in resilience are primarily the result of comparatively high rankings within the social, economic, and institutional subcomponents of the resilience index. A high degree of social homogeneity, diverse economies with elevated levels of property ownership, high employment rates, and the institutional capacities to mitigate the effects of natural disasters are all attributes found in these urban areas.

Hancock, Chattahoochee, Quitman, and Echols County, Georgia; as well as Issaquena County, Mississippi are the five least resilient counties within FEMA Region IV. With the exception of Chattahoochee (which is part of the Columbus, GA-AL metropolitan area, these counties are all rural areas. The low resilience scores here are a function of lower than average infrastructure and institutional resilience, as well as lower scores on the remaining sub-indices (Table 2).

Table 2: Most and Least Resilient Counties

Rank	County	Resilience Score	Social	Economic	Insti-tutional	Infra-structure	Community Capital
Most Resilient							
1	Fayette, KY	3.086	0.751	0.637	0.711	0.474	0.513
2	Jefferson, AL	3.069	0.765	0.625	0.706	0.445	0.528
3	Davidson, TN	3.063	0.765	0.619	0.700	0.487	0.491
4	Pinellas, FL	3.034	0.715	0.567	0.711	0.646	0.395
5	Williamson, TN	3.023	0.835	0.640	0.671	0.316	0.560
6	Durham, NC	2.995	0.733	0.661	0.712	0.405	0.484
7	Fulton, GA	2.983	0.681	0.587	0.667	0.562	0.487
8	Forsyth, NC	2.968	0.774	0.618	0.702	0.395	0.480
9	Franklin, KY	2.957	0.788	0.534	0.667	0.350	0.619
10	Daviess, KY	2.949	0.787	0.587	0.698	0.353	0.524
Least Resilient							
1	Hancock, GA	1.608	0.485	0.453	0.154	0.173	0.343
2	Chattahoochee, GA	1.630	0.749	0.304	0.149	0.213	0.215
3	Quitman, GA	1.672	0.493	0.344	0.421	0.086	0.328
4	Echols, GA	1.696	0.620	0.378	0.277	0.123	0.298
5	Issaquena, MS	1.737	0.463	0.385	0.274	0.243	0.371
6	Taliaferro, GA	1.737	0.487	0.457	0.164	0.220	0.410
7	DeSoto, FL	1.755	0.539	0.300	0.484	0.138	0.293
8	Noxubee, MS	1.771	0.476	0.477	0.173	0.201	0.444
9	Sharkey, MS	1.799	0.490	0.465	0.199	0.203	0.441
10	Grundy, TN	1.808	0.575	0.456	0.185	0.208	0.383

Community Case Studies: Gulfport-Biloxi, Charleston, Memphis

To illustrate the scalability of the resilience metric and to articulate the significance of a component-based approach for objective measurement, we employed a case study by scaling our index from the entire Southeast region to counties within three metropolitan statistical areas: Gulfport-Biloxi MS, Charleston-North Charleston, SC, and Memphis, TN-MS. These three metropolitan areas span thirteen counties, and they are highly diverse in terms of population, income, racial and ethnic identity, and age. We chose these particular urban areas for a case study since they are primary test beds of the Community and Regional Resilience Institute (CARRI). CARRI is a major interdisciplinary research initiative supported by the U.S. Department of Homeland Security and operated by the U.S. Department of Energy's Oak Ridge National Laboratory (see http://www.resilientus.org).

Table 3 presents the delineation of resilience scores for the three metropolitan statistical areas, and Figure 4 shows their spatial distribution. When averaging the composite scores for each test bed, Charleston has the highest overall resilience closely followed by Memphis and Gulfport-Biloxi. However, when you disaggregate the scores by individual county (Figure 4 and Table 3), the driving forces of the composite scores become clear. The primacy of Charleston as the most resilient of the three, for example, is a function of moderate to high levels of resilience among all of its counties, while for Gulfport-Biloxi, only one county, Harrison, has an overall score within the moderate to high level. There is a mixed pattern for the Memphis metro area, which includes counties with very high resilience (Shelby) as well as very low resilience (Tunica), and everything in between.

In examining the individual county profiles across the test beds some interesting findings also appear. Shelby County, TN; Charleston County, SC; DeSoto and Harrison Counties, MS rank highest in terms of their overall disaster resilience. Within this context, the scores for these counties do not diverge significantly, yet the contributions of each of the subcomponents vary considerably between these places. DeSoto County's overall score, for instance, is primarily the product of its high rank for social resilience (social resilience score = 0.913) whereas Shelby County's score is primarily a function of infrastructural and economic resilience (infrastructure resilience = 0.845; economic resilience = 0.716).

To increase the resilience ranking of DeSoto County to a position similar to that of Shelby County, disaster planners and decision makers could concentrate on components other than social, which is already quite good. Striving to increase

Table 3: Resilience of Gulfport-Biloxi, Charleston-North Charleston, and Memphis Metropolitan Statistical Areas

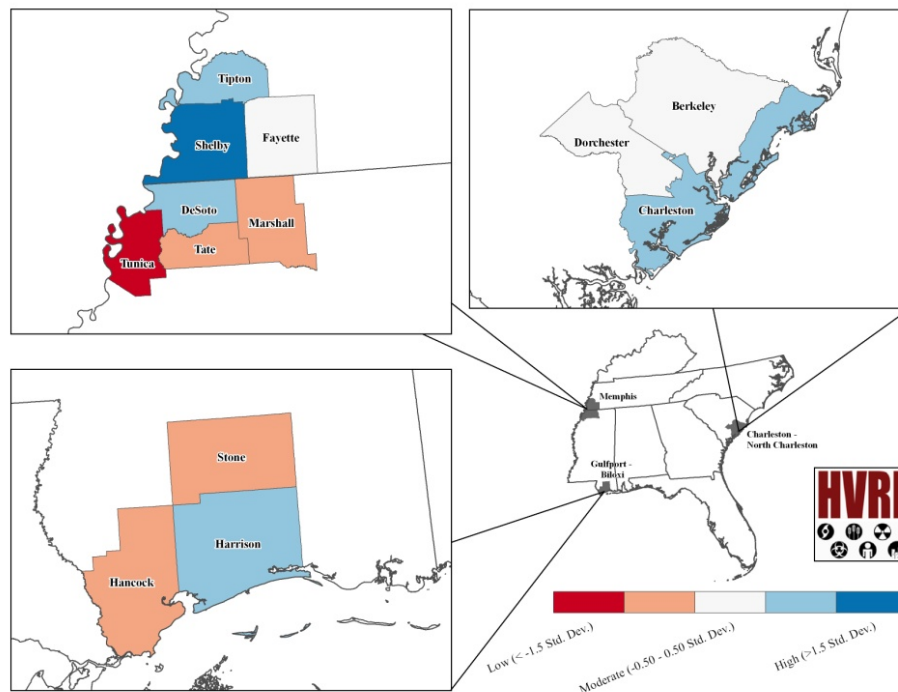|	Resilience Type					
	Social	Economic	Institu-tional	Infra-structure	Community Capital	Resilience Score
Gulfport-Biloxi MSA						**2.271**
Hancock County, MS	0.498	0.409	0.499	0.203	0.499	2.108
Harrison County, MS	0.527	0.552	0.579	0.504	0.660	2.821
Stone County, MS	0.440	0.324	0.324	0.258	0.537	1.883
Charleston-North Charleston MSA						**2.583**
Berkeley County, SC	0.657	0.495	0.554	0.073	0.446	2.216
Charleston County, SC	0.500	0.648	0.702	0.519	0.722	3.091
Dorchester County, SC	0.743	0.549	0.423	0.141	0.586	2.442
Memphis MSA						**2.330**
DeSoto County, MS	0.913	0.557	0.456	0.328	0.501	2.754
Marshall County, MS	0.356	0.537	0.325	0.185	0.351	1.753
Tate County, MS	0.573	0.471	0.287	0.197	0.502	2.031
Tunica County, MS	0.252	0.400	0.401	0.167	0.308	1.528
Fayette, County TN	0.622	0.469	0.429	0.289	0.618	2.427
Shelby County, TN	0.582	0.716	0.499	0.845	0.534	3.175
Tipton County, TN	0.750	0.536	0.527	0.300	0.532	2.646

Figure 4: Spatial patterns of disaster resilience indicators for Gulfport-Biloxi, Charleston, and Memphis metro areas

DeSoto County's rank in infrastructural resilience provides the most fruitful opportunity, yet increases in institutional resilience and community capital may also provide valid starting points. Utilizing such an approach may not only provide officials in the county with a means to benchmark their scores against other counties, it also provides a basis for investment prioritization, and a method for tracking the resilience of a county relative to other counties' scores over time.

Discussion and Conclusion

This paper provides a first-attempt in developing replicable and robust baseline indicators for measuring and monitoring the disaster resilience of places. Because the science of resilience is still in its infancy, incremental empirical developments such as these are necessary to 1) advance our understanding of the multi-dimensional nature of resilience and its constituent parts, but more importantly to 2) provide metrics that are easily understood and applicable to the decision making process. Once established, the **b**aseline **r**esilience **i**ndicators for **c**ommunities (or BRIC for short) provide a useful way to examining not only the composite score when compared to other places such as the comparisons between the three metro areas (inter-metro), but it also enables comparisons within each metro area (intra-metro). While regional authorities may be more interested in the overall patterns and look for intervention strategies that improve the entire region, local leadership (e.g. county level officials) might be more interested in intervention opportunities at the county scale, so they would be more inclined to only examine county level scores.

The efficacy of the baseline resilience indicators to scale up from the county, to the metro area, to the state, to the region, and to the nation is one of the greatest strengths of this approach from a public policy perspective. The other beneficial outcome of this baseline resilience index (BRIC) is the visualization of the results, which provides a quick comparative overview of where improvements in baseline indicators of resilience are most needed. More significantly, these baseline indicators (thanks to their sub-index type of construction methodology) identify which category of intervention (social, economic, infrastructure, institutional, community capacity) would provide overall improvement in the score.

Since BRIC is one of the first empirically based disaster resilience indices, it is not without shortcomings. The most significant is the reliance on national data sources, which are often out of date and inadequate to the task of characterizing local circumstances. While local data could be used, such data would not be comparable or always available across regions. However, if a national effort to obtain resilience indicators data were undertaken, we would suggest a number of important items for inclusion. The most underdeveloped

sub-index is community capacity, so measures of volunteerism at the county level (such as number of people involved in parent-teacher organizations, youth groups, etc.); number of community based organizations; level of innovation within the community; composition and activity level of Community Emergency Response Teams (CERTs) would be useful. In addition, a consistent metric for employment in the tourism sector (by county) and building permits and building code data at the county scale would also be useful.

We suggest that the baseline indicators provide the first "broad brush" of the patterns of disaster resilience within and between places and the underlying factors contributing to it.   A second step is a more detailed analysis within jurisdictions to assess place-specific capacities in each of these areas (social, economic, institutional, infrastructure, community) and the development of fine-tuned and local appropriate mechanisms for enhancing disaster resilience. This baseline resilience index for communities (BRIC) can help in initiating research interest, community discussions, and for attracting public interest and local concern for fostering disaster resilient communities.

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