# Spatial and Temporal Dynamics of Social Vulnerability in the United States from 1970 to 2010:
## A County Trajectory Analysis

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## ABSTRACT

Social vulnerability has been an important concept to characterize the extent to which human society is vulnerable to hazards. Although it is well known that social vulnerability varies across space and over time, there is only a paucity of studies to examine the basic patterns of the spatial and temporal dynamics of the social vulnerability in the United States. This study examines the spatial and temporal dynamics of social vulnerability of the U.S. counties from 1970 to 2010. For each decade, social vulnerability of counties is quantified by the social vulnerability index (SoVI) using county-level social, economic, demographic, and built environment characteristics. The SoVI is mainly designed to quantify the cross-sectional variation of social vulnerability and is not conducive to direct comparison over time. This study implements a methodology that integrates quantile standardization, sequence alignment analysis, and cluster analysis to investigate how social vulnerability of U.S. counties has changed over time. The authors find that U.S. counties exhibit distinctive spatial and longitudinal patterns, and there are counties/areas which have persistent high or low social vulnerability as well as frequent change in their social vulnerability over time. The results can be useful for policymakers, disaster managers, planning officials, and social scientists in general.

## KEYWORDS

## INTRODUCTION

Social vulnerability is an essential concept to understand the extent to which human society is vulnerable to natural disasters (Cutter & Finch, 2008). As the human population has experienced extraordinary growth, redistribution, and compositional change across the world, both the social and natural environments of the world have been significantly altered. As the result, the anthropogenic factors, such as deforestation, land use change, and excessive emission of greenhouse gases have become the major drivers that accelerate the global climate change (National Academies of Sciences,

2016). The changing global climate is likely to increase the intensity and severity of natural hazards – such as heat waves, droughts, wildfires, floods, and tropical cyclones (Van Aalst, 2006). Many rapidly growing human communities in the United States are increasingly exposed and vulnerable to the natural hazards (Flanagan, Gregory, Hallisey, Heitgerd, & Lewis, 2011). Assessing the extent to which the United States is vulnerable to natural hazards in space and over time is fundamental to prepare for, counteract, and mitigate potential damages from natural hazards (Cutter, 1996; Van Aalst, 2006). This study investigates how social vulnerability of counties in the United States has evolved in space and over time from 1970 to 2010.

It is well known that the severity of the aftermath of natural hazards is not only directly affected by the geophysical characteristics of the hazard events, but also compounded by the social characteristics of the affected populations (Cutter, 1996; Tobin & Montz, 1997). The at-risk populations of different social characteristics can disproportionately magnify or attenuate the impacts of natural hazards as they have differential capacity to adapt to and recover from exogenous perturbations (Adger, 2006; Cutter, 2001; Turner et al., 2003). Socially vulnerable populations are likely to suffer greater disruption in the wake of natural hazards due to the lack of resources and coping capacity (Cutter, 2001, 2009; Wisner, Blaikie, Cannon, & Davis, 2004). As such, natural disasters are an outgrowth of social vulnerability and can be considered socially produced, or "unnatural" (Laska & Morrow, 2006; Logan, 2009; N. Smith, 2006; Wisner et al., 2004). Assessing social vulnerability is fundamental to understand how human society is vulnerable to natural hazards and can be prepared with preventive mitigation strategies.

Social vulnerability is often assessed by social vulnerability index (SoVI), which was first introduced by Cutter, Boruff, and Shirley (2003), and has since been widely used to assess the relative level of social vulnerability at various geographic scales based upon the underlying demographic and socio-economic characteristics. The SoVI is a composite index that can help better understand the cross-sectional and spatial variation of social vulnerability. Following Cutter et al. (2003)'s approach, many studies have used SoVI to measure the spatial distribution of social vulnerability to all natural hazards or specific hazard events such as floods, tsunami, sea-level rise, and hurricanes (Burton & Cutter, 2008; Flanagan et al., 2011; Myers, Slack, & Singelmann, 2008; Rufat, Tate, Burton, & Maroof, 2015; Rygel, O'sullivan, & Yarnal, 2006; Wang & Yarnal, 2012; Wood, Burton, & Cutter, 2010; Wu, Yarnal, & Fisher, 2002; Yoon, 2012; Zahran, Brody, Peacock, Vedlitz, & Grover, 2008). In particular, mapping SoVI is very often used to reveal the regional discrepancy and spatial variation of social vulnerability (Cutter et al., 2003; Cutter & Finch, 2008; D. King & MacGregor, 2000; Morrow, 1999).

Most social vulnerability studies take a place-based approach, in which social vulnerability to potential hazards is inferred by considering social economic and demographic characteristics of places (Cutter, 1996, 2009). In the past few decades, the U.S. population has experienced significant growth, diversification, and spatial reallocation (Donner & Rodríguez, 2008; Magnus, 2008; Thomas, Phillips, Lovekamp, & Fothergill, 2013). The changing geo-demographics must have altered social vulnerability of places across the United States. This study investigates the major patterns in the spatial and temporal dynamics of social vulnerability of U.S. counties from 1970 to 2010. As such, this study considers social vulnerability as a spatial and temporal process evolving over time and across space, and it sheds light on the spatial patterns as well as the temporal dynamics of social vulnerability in the United States from 1970 to 2010.

In particular, this study attempts to understand: the prominent trajectories of social vulnerability change of U.S. counties over time; the extent to which the county level social vulnerability is stationary or mutable over time; and the locations where social vulnerability have deteriorated over time. This study employs a methodology that compares the U.S. counties' changing social vulnerability to understand their similar or different trajectories. The trajectories of social vulnerability shed light on the pathways by which U.S. counties' vulnerability has been transitional over time.

The rest of the paper proceeds as follows. The second section reviews the conceptualization of social vulnerability as a spatial and temporal dynamics. The third section introduces the methodology

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