Chapter 1
Social Vulnerability and Geohazards: Review and Implications

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Abstract Vulnerability assessment associated with natural hazards is a complex process that needs to account for multiple dimensions of vulnerability, including both physical and social factors. Physical vulnerability is a function of the intensity, magnitude, and frequency of the hazard, the degree of physical protection provided by the natural and built environment, and/or the resistance levels of the exposed elements. On the other hand, social factors such as preparedness and institutional and non-institutional abilities for handling natural hazards events are also important elements for a society's vulnerability to natural hazards. Social vulnerability refers to the underlying factors leading to the inability of people, organizations, and societies to withstand impacts from the natural hazards. The concept of social vulnerability has been used widely to understand individuals' and groups' vulnerability in terms of preparing and recovering from natural disasters.

Geohazards, such as earthquake, landslide, sinkhole, land subsidence, coastal erosion, etc., are not the only natural hazards with large uncertainties at the extreme end of the hazard spectrum and with potentially large impacts on humanity. Increasing global resilience and reducing the disasters induced by the occurrence of extreme hazards at an acceptable economic cost requires a solid-scientific understanding of

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the hazards: from understanding of the physics of different geohazards, their analysis and monitoring, through interpretation, modeling, hazard assessment, and forecasting of single or concatenated events, to delivery of the scientific forecasts to disaster management authorities. However, the detrimental impact of specific types of geohazards on vulnerable and marginalized groups has not been studied further.

The proposed book chapter will review and investigate implications of social vulnerability to different geohazards. It can be hypothesized that social vulnerability is likely to vary with the type and mode of the geohazard, the rate of onset of the geohazard, the velocities, the area affected, and the geohazard's temporal persistence in the environment. First, the book chapter will present how the concept of social vulnerability can be applied to expand our understanding on the specific geohazards' socio-economic impact. Additionally, the book chapter will cover the literature that examined the differential impacts of geohazards on various groups within our society caused by the differences in socioeconomic status (SES). Last, the chapter will present specific domestic and international case studies to illustrate examples of geohazards and introduce the detrimental socio-economic impacts on the given community. Examples include, but not limited to, sinkholes in central Florida, land subsidence in South Korea, earthquakes in California, and more.

Keywords Geohazards · Social vulnerability · Global resilience · Disasters

1.1 Introduction

Geohazards, such as floods, earthquakes, tsunamis, sinkhole, and landslides have caused and are increasingly causing significant loss of life and property. These losses predominately occur during extreme, high impact events. The scale of these geo-disasters caused by geohazards is illustrated in the long-lasting societal and economic impacts that come as a result of recent extreme events. To reduce geo-disasters induced by extreme hazards in a cost-effective manner and increase global resilience to geohazards, there needs to be a solid-scientific understanding of these hazards.

Due to a growing population expanding into hazardous areas, there has been a rapid increase in the loss of life and property as a result of natural hazards, particularly geohazards. Cities, especially in areas that experience high levels of poverty and vulnerability, are sprawling into hazardous areas, resulting in people working and living in poorly constructed buildings. All people living in hazardous areas are considered part of a vulnerable population; however, the social impacts of this type of exposure tend to disproportionately fall on those in society-minorities. Often, these groups are the least prepared for an emergency and have less access to resources to adequately prepare for geo-disasters. Another contributing factor is the tendency to live in substandard housing in high-risk locations while also lacking the knowledge or connections necessary to access resources to speed up the recovery process (Dunning and Durden 2011; National Research Council 2006).

The effects of geo-disasters can be long-lasting and disruptive while threatening the well-being and safety of individuals, families, and communities (Gillespie and Danso 2010). Unfortunately, proper disaster response and recovery requires a vast amount of financial and community resources, which are not always sufficient in meeting the needs of those most vulnerable. The impact of disasters can be felt community-wide, but socially vulnerable populations tend to be disproportionately impacted by altered community fabric, economic hardship, and compromised mental and physical health (Bergstrand et al. 2015).

The term social vulnerability can be defined as people's "capacity to anticipate, cope with, resist and recover from the impacts of a natural hazard" (Wisner et al. 2004). This differs from one's physical vulnerability which focuses on the susceptibility to biological changes, such as physiological functioning and anatomical structure, and instead focuses on vulnerability to behavioral changes. There is an array of social factors that disproportionately impact an individual or communities' level of social vulnerability during a disaster (Benevolenza and DeRigne 2019; Singh et al. 2014). During and after a disaster, individuals living with physical or mental health challenges, immigrants, older or dependent adults, children, refugees, and people living in poverty are among the most socially vulnerable (Amaratunga and O'Sullivan 2006; McDermott et al. 2016; Peek and Stough 2010). These individuals tend to be less equipped for emergencies making them more likely to be displaced from their home, separated from family members, or require assistance to meet basic needs after disasters strike (Rufat et al. 2015; Vu and Vanlandingham 2012). Socially vulnerable populations also experience some disproportionate risks during the disaster recovery stage as well. Some of these risks include experiencing disproportionate amounts of abuse and neglect, mental health pathology (i.e., post-traumatic stress symptoms (PTSS) and depression) and have a higher chance of contracting diseases as a result of poor living conditions (Amaratunga and O'Sullivan 2006; Boscarino et al. 2014; Gutman and Yon 2014; Jia et al. 2010; Kouadio et al. 2012; La Greca et al. 2019; Parkinson and Zara 2013).

Much of the previous research and literature on social vulnerability during disasters were focused on hurricane survivors. One of these studies, conducted after Hurricane Katrina, found that mental and physical health symptoms among Vietnamese immigrants were significantly higher 1-year post-disaster than they were pre-disaster (Vu and Vanlandingham 2012). Another study found that in China after the 2008 Sichuan earthquake, older adults were 14.5% more likely to demonstrate PTSS than younger adults (Jia et al. 2010). Previous literature has consistently observed that children show higher-risk levels for experiencing post-disaster physical and mental health impairments than adults based on an association with their dependence on caregivers, having fewer coping resources, and a developing brain (Becker-Blease et al. 2010; Goldmann and Galea 2014; Rufat et al. 2015).

Being that individuals with inadequate socioeconomic resources are more likely to be living in polluted, low-lying areas prior to disaster, they are at a disproportionate risk of experiencing malnutrition, physical injury, and waterborne and respiratory diseases when compared to those with greater economic means (Keim 2011; Zoraster 2010). It has also been found that collapse of healthcare infrastructure, inability to access basic needs, and lack of insurance contribute to the high mortality rates of socially vulnerable disaster-affected populations (Curtis et al. 2007; Smiley et al. 2018; Zoraster 2010). One example of this was demonstrated after Hurricane Katrina where mortality rates were the highest among those living in poverty and older adults (Zoraster 2010).

Over the past 20 years, the idea of social vulnerability has started to gain significant attention. Further research is needed to understand the factors that increase the level of risk for individuals, families, and communities living in disaster-affected regions (Bergstrand et al. 2015). Exploring these factors further can enhance recovery and response practices to better serve socially vulnerable populations throughout all phases of a disaster.

In this paper, we have reviewed and investigated implications of social vulnerability to different geohazards in four sections. The first section we summarize mechanisms and characteristics of different geohazard types to expand our scientific/engineering understanding of those geohazards. The second presents the concept of how social vulnerability can be applied to expand our understanding on geohazards' socioeconomic impact. The third chapter will present specific international and domestic case studies that illustrate examples of geohazards and introduce the detrimental socioeconomic impacts on a community. The last chapter will discuss the differential impacts of geohazards to our society caused by the differences in socioeconomic status (SES).

1.2 Extreme Geohazards: Mechanism and Characteristics

This section summarizes mechanism and characteristics of different types of extreme geohazards that create the physical and social impacts to a community. By scientific understanding, engineering design and mitigation measures can be improved to reduce the social vulnerability of geohazards.

1.2.1 Flood Due to Extreme Water Events

The US national planning scenarios mainly focus on earthquakes and hurricanes as natural hazards. An important addition would be large-scale flood events. This is an important addition, in part, because from 1960 to 2005 27% of all property loss and 17% of fatalities from natural hazards have been due to floods (CEMHS 2020). Events such as hurricanes or large-scale storms often cause geosystem failures due to overloading.

Specifically, a levee is like a wall that contains or hold back water, and it can fail due to breach. A breach creates an opening for water to flood through. There are three failure mechanisms of levee breach (see Fig. 1.1), explained below.

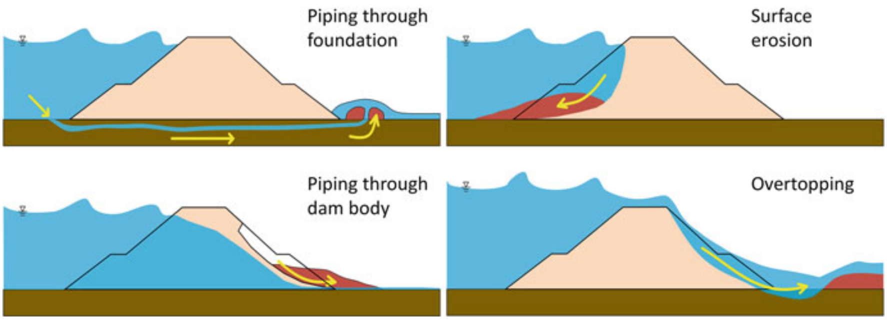


Fig. 1.1 Overview of main levee failure mechanisms

Foundation failure: A breach caused by surface erosion or subsurface failure. These are often accompanied by levee boils or sand boils. Boils indicate instability that can lead to internal soil erosion of the levee foundation, sinking of the levee, or, according to some engineers, piping (progression of internal soil erosion through levee system) that undermines the levee.

Erosion and damage: Erosion of the surface of the levee caused by winds and water. This is worsened by new or already existing damage to the levee. The less surface protection, the more likely erosion will occur. Trees and floating objects also cause erosion and damage of levee.

Overtopping: This is one of the major causes of levee failure. This is created when flood water levels are higher than the levee or high winds create a storm surge that causes waves to crash over the levee. This can lead to surface erosion of the levee or create a full-on breach.

Levees received significant public attention after the Hurricane Katrina levee failure, in New Orleans. There were over 50 levee breaches that resulted in the submerging of 80% of the city. Most levee breaches were due to overtopping while others failed due to water passing underneath the levee causing the levee wall to shift. Over 1464 people died following these breaches. Further information will follow in Sect. 1.5.

1.2.2 *Earthquake*

Earthquakes are the result of sudden movements in the cracks of the Earth's crust, called faults. This sudden movement releases stored energy in waves that spread through the Earth causing the ground to shake.

Earthquakes are a risk for about 75 million Americans. Earthquakes are the costliest natural hazards in the United States. The Northridge, California earthquake in 1994 had a magnitude of 6.7 and killed 33 individuals, injured 9000, and displaced over 20,000 people. A repeat of earthquakes like the 1906 San Francisco

The upper level of Interstate 880 in Oakland, California, U.SA., collapsed during the Loma Prieta earthquake (M=6.9) on October 17, 1989. 41 people were killed

This business in Seattle was heavily damaged during the Nisqually, Wash., earthquake (M=6.8) on February 28, 2001. About 400 people were injured

Building collapse in Paso Robles, Calif., during San Simeon, Calif., earthquake (M=6.5) on December 22, 2003. 2 people were killed

Fig. 1.2 Example photos of earthquake damages (photos from USGS 2006)

earthquake or the 1811–1812 could cause damage estimated over $500 billion. According to the Federal Emergency Management Agency, FEMA, the estimated cost for future yearly earthquake losses in the USA will be around $5.6 billion a year (GAO 2007).

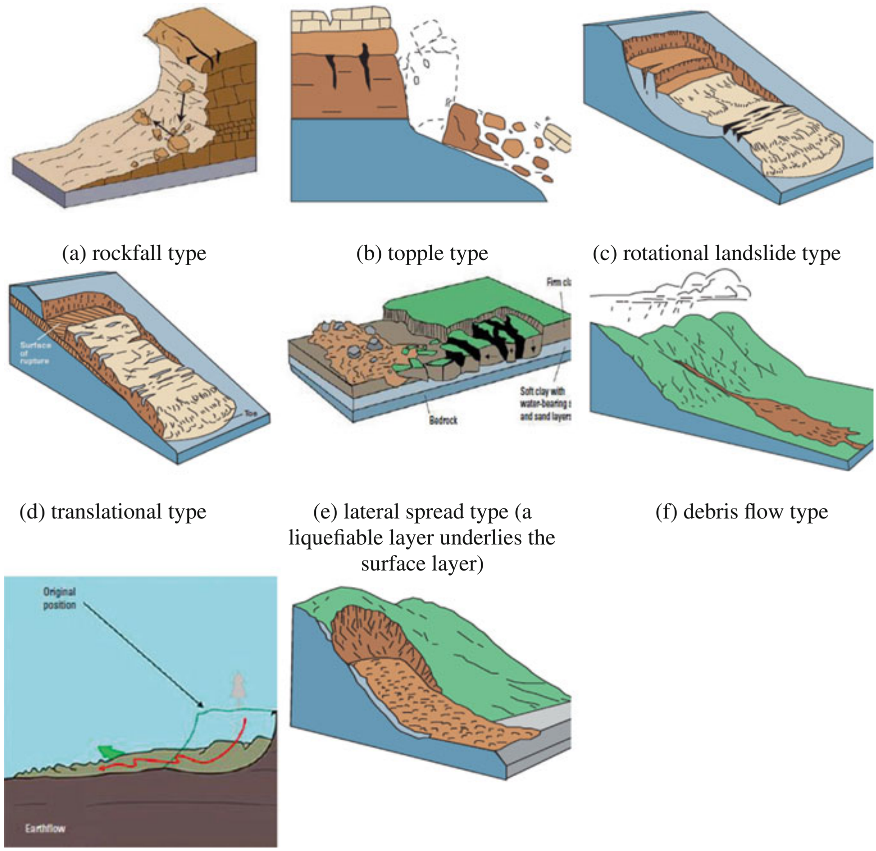
Below are examples of infrastructure damages due to earthquakes in California; see Fig. 1.2. There are two plates in California, the Pacific Plate and the North American Plate. The Pacific plate includes most of the Pacific Ocean and the California Coastline. The North American Plate consists of parts of the Atlantic Ocean and most of North America. The primary boundary between these plates is the San Andreas Fault, created by several small faults, like the Hayward Fault. It is more than 650 miles long and has a depth of at least 10 miles (USGS 2013). The Pacific plate grinds past the North American plate. The San Andreas Fault adapts to this movement. This adaptation causes tiny shocks, earth tremors, and strains that produce earthquakes when released.

1.2.3 Landslide

It is important to understand the potential landslide hazard when moving to hilly or mountainous terrain and how to plan for them. Planning includes proper land-use, new construction techniques, and infrastructure created to reduce the costs of landslides.

Landslides are essentially the movement of a mass of rocks, debris, or earth down a slope. There are five modes of slope movement: falls, topples, slides, spreads, and flows (see Fig. 1.3).

Landslides usually have multiple causes that increase the effects of down-slope forces, decreased strength, or increased strength. Slope movement occurs when the forces going down slope are stronger than the material that the slope is made



(a) rockfall type (b) topple type (c) rotational landslide type

(d) translational type (e) lateral spread type (a liquefiable layer underlies the surface layer) (f) debris flow type

(g) earth flow type (f) debris avalanche type

Fig. 1.3 Failure mechanisms of landslide (Highland and Bobrowsky 2008) (figures from USGS 2018)

of. Sometimes landslides are caused by things like water level changes, water infiltration, earthquakes, or a combination of factors. Landslides occur underwater and on land. Landslides underwater, called submarine landslides, cause tsunamis that can damage coastal areas.

In the USA up to 50 people are killed by landslides each year, compared to worldwide death toll of thousands each year (Highland and Bobrowsky 2008; USGS 2018). Most deaths were caused my falling rocks, debris, or volcanic debris. In Montecito, Santa Barbara County, California, a landslide, caused by debris, resulted in 23 deaths, 167 injuries, and more than 400 homes damaged. The debris was triggered by heavy rain falling on steep hillsides, burned in the Thomas Wildfire.

1.2.4 Sinkhole (Natural and Anthropogenic)

Natural Karst Sinkholes In karst areas, sinkholes are common. There are six classifications of sinkholes based on the combinations of two groups (Beck 2012; Gutiérrez et al. 2014; Waltham and Fookes 2003). A subsidence and collapse sinkhole meets two criteria: (1) the type of material, cover, bedrock, or caprock that is affected by erosion/deformation processes and (2) the subsidence mechanism, collapse and suffusion (or sagging) of the substratum that occurs. Unlike other sinkholes, Florida sinkholes have a unique formation process in which they are composed of sandy cover soils, cohesive soils, and weathered limestone. Groundwater tends to be shallow, and the groundwater discharge and recharge is common. This unique formation, along with groundwater flow, causes erosion, a major mechanism of sinkhole creation.

There are three kinds of sinkholes in Florida, dissolution, cover subsidence, and cover-collapse (Tihansky 1999). Dissolution sinkholes usually occur in mantled karst areas that contain bedrocks that are shallow. In a dissolution sinkhole, rainwater and runoff flow through the cracks of bedrock, dissolving it. Subsidence sinkholes and collapse sinkholes are shown in Fig. 1.4. Subsidence sinkholes can be found in permeable, non-cohesive soils, like sand. Collapse sinkholes can be found in areas with cohesive and impermeable soils. According to a research study, cover-collapse sinkholes are frequent in areas that contain an overburden thickness of 60 m

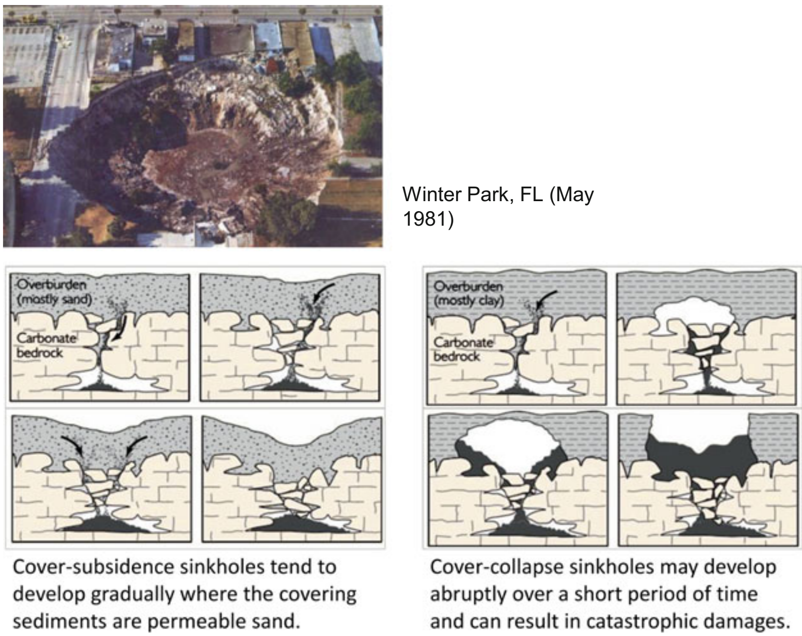


Fig. 1.4 Sinkholes in Florida and formation mechanism (modified from Tihansky (1999), photo from USGS)

Fig. 1.5 Photographs of urban road sinkholes that were due to an underground void in the area: (**a**) Seokchon Station in Seoul, Korea (August 2014), and (**b**) Incheon, Korea (July 2014) (modified from Nam et al. 2018)

and significant clay contents (Sinclair and Stewart 1985). In recent research, it is clear that researchers have strived to explore the hydrogeological (Nam et al. 2020; Xiao et al. 2016; Perez et al. 2016) and geo-mechanical mechanism (Soliman et al. 2019, Nam and Shamet 2020, Shamet and Nam 2021) of sinkhole formation. In addition, the sinkhole susceptibility modeling and mapping has been studied (Kim and Nam 2018; Kim et al. 2020).

Urban Sinkholes Metropolitan cities, like Tokyo or Seoul, have experienced ground collapse and/or sinkholes in the road (Nam et al. 2018). Underground construction and infrastructure are excessive in these cities. When cities age, so do their underground infrastructure. With age, the structural conditions become poor. An example of poor conditions include leakage of water and sewage pipelines that cause soil loss creating underground cavities. When the cavities grow and move toward the ground surface, the ground collapses or a sinkhole happens, Fig. 1.5. These events cause death and damage.

1.2.5 Subsidence

A land subsidence occurs when there is a sudden sinking of the Earth's surface from the removal or displacement of subsurface earth materials. Subsidence ranges from small, local collapses to regional surfaces. The causes of land subsidence include oxidation of soil or peat, dissolution in limestone aquifers, wetting of soils with little moisture and low density, compaction, liquefaction, subterranean mining, and fluid withdrawal, like groundwater or petroleum.

More than 17,000 square miles in 45 States have been affected by subsidence (Galloway et al. 1999). In California, the largest cause of subsidence is due to excessive ground water pumping causing compaction of receptive aquifer systems. In fact, over 5200 miles of land is affected by subsidence in the San Joaquin Valley in California; Fig. 1.6 shows the land surface in 1925 and a man standing for

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<td>Approximate 9-m subsidence in the San Joaquin Valley, California from 1925 to 1977 due to groundwater pumping. (from Galloway et al. (1999), photo from USGS)</td>
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Photos showing the flood and subsidence-induced damages in Miami Beach, FL, U.S.A. (Wdowinski et al., 2020)</td>
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Fig. 1.6 Example photos of land subsidence and building damages

comparison, in 1977. The second largest cause of subsidence in California is oxidation of soils. Subsidence caused by decomposition of soil is also a major cause of subsidence in Florida, specifically in the Everglades.

In addition, in coastal areas, subsidence is a problem along with rising sea levels. In the past 10 years, coastal communities in southeast Florida have had an increase in flooding, causing problems with property, commerce, and quality of life. This increase in flooding can be attributed to global, regional, and local processes that are affecting elevation differences between coastal communities and the sea level. In a research article, researchers monitored subsidence in coastal areas in southeast Florida, using Interferometry Synthetic Aperture Radar. They did this to evaluate how local subsidence is contributing to increased coastal flooding (Wdowinski et al. 2020). Their results indicate that subsidence occurs in localized area (<0.02 km^2) extending up to 3 mm per year, in urban areas built on reclaimed marshland.

1.3 Societal Impacts of Geo-Disasters

Individuals with lower socioeconomic status (SES) have been found to have increased vulnerability in regard to disasters. In addition, individuals with lower socioeconomic status have an increased likelihood of suffering from the adverse effects and consequences. Such consequences include, but are not limited to, property damage, homelessness, physical impacts, and financial hardship. Due to financial hardships caused by disasters, natural disasters make it so those

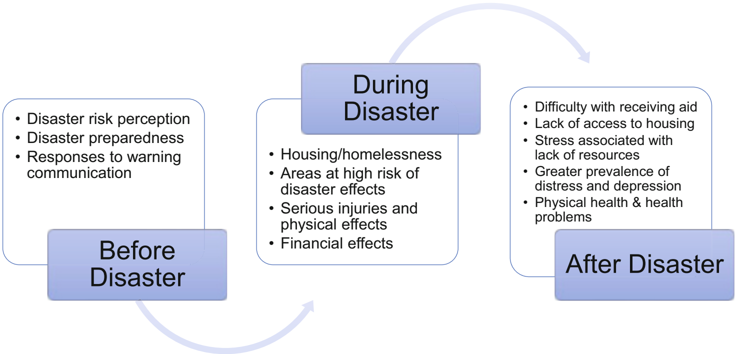

Fig. 1.7 Illustration of how disasters affect people of low socioeconomic status

impoverished are more likely to stay that way, according to the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) (Hallegatte et al. 2017). Figure 1.7 presents the chart to illustrate how disasters affect people of low socioeconomic status in the phase of before, during, and after a disaster.

1.3.1 Before Disaster

Understanding disaster risk, how to prepare for a disaster, and how to respond may be affected by the socioeconomic status of individuals. Research on the relationship between SES and natural disasters has shown that individuals with varying SES prepare and respond to disasters differently, due to many factors, specifically, those of lower socioeconomic status.

1.3.1.1 Perception of Disaster Risk

Fothergill and Peek (2004) conducted a literature review focusing on individuals in poverty and their unique experiences with disaster. They reported mixed findings on the perception of disaster risk. Some studies they cited concluded individuals of lower incomes perceived increased disaster risk and were more concerned than individuals with higher incomes (Flynn et al. 1994; Palm and Carroll 1998; Pilisuk et al. 1987). These findings were specifically in regard to both natural disasters and technological disasters. For reference, natural disasters are defined as disasters that are a result of earth's natural processes, such as hurricanes and earthquakes. On the other hand, technological disasters are disasters caused by human error or a malfunction of a technological structure (Lindsey et al. 2011). However, Fothergill and Peek (2004) also cited research that concluded that individuals with lower SES and individuals whose jobs involve, at least in part, exposure to risk, with fewer resources that those with more, are less aware of the risks associated with their work.

Due to conflicting findings, Fothergill and Peek (2004) concluded socioeconomic status is a potential contributor and predictor of how disaster risk is perceived and how individuals respond to the perceived risk (Vaughan 1995) and as such SES should be considered when looking at disaster response.

1.3.1.2 Disaster Preparedness

A study was conducted at the National Center for Disaster Preparedness at Columbia University that found two-thirds of all respondent household, about 65%, either reported no disaster plans or had an inadequate disaster plan (Petkova et al. 2016). According to data from the FEMA, less the 50% of Americans are familiar with local hazards, less the 40% of Americans have an emergency plan for their household, and around 52% have disaster supplies at home (Federal Emergency Management Agency 2014).

In looking at the disaster preparation and SES research, Fothergill and Peek (2004) found that individuals with lower income, less education, and living in poverty are less prepared for disaster (Turner et al. 1986; Vaughan 1995). It was concluded that potential reasons for lack of preparedness could be the cost of preparation. Such costly preparation includes flood insurance or owning a home with increased earthquake resilience (Fothergill 2004; Palm and Carroll 1998). The report on impacts of natural disasters, from the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR), concluded poorer individuals, with fewer resources, don't spend as much on preventing or mitigating the adverse effects of natural disasters. In other words, globally, those with higher incomes and increased access to resources tend to invest more on both preventing and reducing the effects of natural disasters (Hallegatte et al. 2017).

Another study focused on 1504 adults who are 50 years old or older and how prepared they were for a disaster. The researchers found that the adults with lower income were less prepared than the adults with higher income (Al-Rousan et al. 2014). So, in addition to income, older age is a kind of vulnerability that can affect how people prepare and respond to disaster.

1.3.1.3 Responses to Warning Communication

Research suggests individuals with lower SES potentially may not properly respond to warnings about disaster. Fothergill and Peek (2004) found that groups including poor females, individuals with lower income, individuals in public housing, homeless women, and the unemployed do not have sufficient money or the resources to evacuate even after receiving an official warning to do so. Lack of money or resources makes it harder to respond, unlike those with higher SES (Gladwin and Peacock 1997; Morrow 1997; Morrow and Enarson 1996). Thiede and Brown

(2013) found that African Americans and people with a high school education, or lower, were less likely to evacuate after the flooding due to Hurricane Katrina. These respondents did not evacuate before the storm, despite warnings to do so. They were unable to evacuate due to reasons such as lack of money, lack of transportation, no place to go, or job requirements. These individuals were more than twice as likely to be unable to evacuate than individuals with at least some level of college education (Thiede and Brown 2013).

1.3.2 During Disaster

The mechanisms of Disaster Impact include (1) housing and homelessness, (2) residence in areas at high risk of disaster effects, (3) more serious injuries and physical effects, and (4) financial effects.

1.3.2.1 Housing and Homelessness

Across the globe, individuals with lower SES are more likely to live in homes more vulnerable to disaster impact. This results in increased material losses after the disaster, less protection from disaster, and greater damage and destruction.

While looking at prior research, Fothergill and Peek (2004) found that individuals with lower SES were at increased risk of hazards, damage, and destruction of property. This was due to living in homes with lower-quality construction (Austin and Schill 1994; Bolin and Bolton 1986; Greene 1992; Phillips and Ephraim 1992; Phillips 1993); older homes (Comerio et al. 1994); or mobile home (U.S. Department of Commerce 1995). The World Bank and GFDRR reported poorer individuals live in more vulnerable homes, globally. When looking at over 200 countries, the poorest 20% of individuals were a little less than two times more likely to live in fragile homes (Hallegatte et al. 2017).

Fothergill and Peek (2004) also concluded that disasters, in some cases, most likely resulted in more low-income individuals becoming homeless. They cited research that looked at the effects of the Loma Prieta earthquake (California, USA). This earthquake was more likely to cause homelessness for individuals with low income. In addition, Hurricane Hugo led to homelessness for around 60,000 people, in which many had low income (Federal Emergency Management Agency 1990; Phillips 1998).

1.3.2.2 Residence in Areas at High Risk of Disaster Effects

Observing trends among individuals at all levels of wealth and poverty, living in high-risk disaster locations, the World Bank and GFDRR report, “From 1970 to 2010 the world population grew by 87 percent, while the population in flood plains increased by 114 percent and in cyclone-prone coastlines by 192 percent" (Global Facility for Disaster Reduction and Recovery (GFDRR) 2016; Hallegatte et al. 2017). In addition, they cited assessment of damages from natural disasters. This showed that costs of damages from natural disasters have increased from 1976 to 1985 and from 2005 to 2014. They found that the increase was more than tenfold, from around $14 billion to $140 billion (Global Facility for Disaster Reduction and Recovery (GFDRR) 2016, as cited in Hallegatte et al. 2017). The World Bank and GFDRR also reported that people in poverty are more likely to live in areas at high risk of disaster impacts potentially because the more dangerous an area is, the cheaper and more available they tend to be (Hallegatte et al. 2017). In addition, they concluded, people in poverty are more likely to have to endure high temperatures and droughts by virtue of where they live. They found mixed results regarding the correlation between poverty and living in high flood areas; however, it is less ambiguous in urban areas. They found that in more countries, about 73% of the populations they observed, poor urban households had increased exposure to floods, but this kind of pattern was not found for rural households (Hallegatte et al. 2017).

In a paper about the effects of Superstorm Sandy, the authors analyzed the demographics of flooded areas and reported that New York City had 812 high-poverty census tracts at the time of the storm but only 44 of those tracts were flooded. They found that there was a larger percentage of the population in flooded tracts below the poverty line than those in non-flooded tracts. The difference was 18.7% below the poverty line compared to 14.7% in non-flooded tracts. In addition, the author also found statistically significant results between race and age. Poor black New Yorkers were more likely to live in flooded areas. Latinos, in contrast, were less likely to live in flooded areas. White individuals in flooded areas were more likely to be 65 years old or older and had higher rates of poverty than their white counterparts in non-flooded areas or drier areas (Faber 2015).

1.3.2.3 Financial Effects

From an economic standpoint, disasters have a proportionally greater effect on poor people around the world, as $92 billion in 2015 was the calculated economic loss from natural disasters with average annual losses being estimated at more than $300 billion a year. This applies to the geo-disasters in the same way. This kind of information fails to present how disasters affect the well-being of the individuals effected by the economic losses. The severity of the $92 billion loss truly depends on who is experiencing the loss. Losing a certain amount of money to one person isn't going to be the same as the loss felt by another. The same loss effects the poor more than the rich because they depend on it more, their lives depend on fewer assets, their consumption is closer to subsistence levels, they cannot rely on savings as readily as the rich, both their health and education is at an increased risk, and the time needed to recover is increased. Focusing on aggregate losses does not give attention to the poor; it instead focuses on how disaster affects people who have enough money to actually lose money.

The report continued to examine the greater vulnerability the poor face. It was noted that savings are concentrated more in homes and livestock for the poor. After a disaster, homes and livestock are likely to be damaged or lost (Moser and Felton 2007; Nkedianye et al. 2011). The wealthy are more likely to put their savings in financial institutions. This kind of savings provides protection against natural disasters. This gives further insight as to how and why natural disasters increase the poverty population, globally, by 26 million each year (The World Bank 2016).

1.3.3 After Disaster

This section covers differences linked to being of low SES and access to disaster aid and important resources, stress and depression, posttraumatic stress and growth, and physical health.

1.3.3.1 Difficulty of Obtaining and Receiving Aid

There are many barriers lower income individuals and people living in poverty face when trying to receive housing, among other aids, from bureaucratic systems. Some barriers include lack of knowledge about where to receive aid, discomfort with the systems survivors go through to get aid, and issues getting to and from disaster assistance centers, as well as child care difficulties and work scheduling conflicts (Dash et al. 1997; Fothergill 2004; Rovai 1994).

In coping with disaster consequences and losses, many individuals, across the globe, must rely on non-disaster aid problems. However, this kind of aid has many limits. For example, these programs are not funded or designed in a way that would allow them to have a quick response time after a disaster. Additionally, funds transferred to people with wealth are usually higher than the transfer of funds to people in poverty. If you look at the USA, transfers from non-disaster programs, like unemployment insurance, are larger than earning losses for category 1 and 2 hurricanes, but lower for category 3 and higher (Deryugina 2017). This clearly shows that non-disaster aid programs are not sufficient in offsetting disaster-related financial losses, even for a country that is on the wealthier side, like the USA.

1.3.3.2 Lack of Access to Housing

As previously stated, individuals with low SES, globally, are more likely to live in homes that are vulnerable to damage after a disaster. Many researchers have reported that many individuals who become homeless after a disaster are people of low SES (Katayama 1992; Phillips and Ephraim 1992). Additionally, they discuss further evidence that housing is often a major issue for people of low SES following a disaster—due to lack of housing because of the disaster, fewer programs for people with low incomes, and the time required for rebuilding coupled with lack of capacity in agencies to provide the low-income housing needed after a disaster (Comerio et al. 1994; Greene 1992; Quarantelli 1993).

In addition, they highlighted research that mentioned the specific low SES groups that have problems in receiving post-disaster aid such as housing loans. These groups include people with less than or average incomes, people with unreliable employment, low-income families, and older adults living in poverty (Bolin 1993; Childers 1999; Fothergill 2004). In addition, Fothergill and Peek (2004) indicated that housing is a major problem for low SES individuals after a disaster for many reasons. These reasons include fewer programs for low SES individuals, the amount of time needed to rebuild, lack of housing post-disaster, and lack of program capacity post-disaster (Comerio et al. 1994; Greene 1992; Quarantelli 1993).

1.3.3.3 Stress Associated with Lack of Resources

A multitude of studies concluded that low-income and low SES homes lacked access to much needed resources after a disaster. Due to this, these individuals tend to have a harder time in dealing with post-disaster stress. Loss due to disaster can increase any stress the individual(s) may be feeling whether it be pre-disaster or post (Bolin and Stanford 1998; Bolin and Bolton 1986; Hewitt 1997; Tierney 1988). In an article that examined a rapid needs assessment conducted in the Rockaway Peninsula, approximately 3 weeks after Superstorm Sandy, authors found that lower-income households were at an increased risk to be worried about food than individuals from higher-income households (Subaiya et al. 2014). In addition, higher SES households were 4.5 times more likely to leave the area to obtain food, due in part to being more likely to have access to transportation. Due to post-disaster damage and destruction, lower SES households probably had a harder time getting to grocery stores and as a result were more worried about food (Marritz 2012; Subaiya et al. 2014). In addition, low SES households showed a pattern of psychological disturbance but not enough to be statistically significant.

1.3.3.4 Greater Prevalence of Distress and Depression

Two factors related to low SES were found to be connected to increased risk of depression, after Hurricane Ike (Tracy et al. 2011). They found that the adults from lower-income households and less education reported more depressive symptoms. Researchers believe this correlation may suggest underlying vulnerabilities among low SES households that increase risk of psychopathological symptoms post-disaster. Other studies were also mentioned that show the same correlation between low SES households and increased risk of depression (Ginexi et al. 2000; Norris et al. 2002; Person et al. 2006) as cited in Tracy et al. (2011). Fan et al. (2015) found two factors related to SES which included unemployment and having a yearly income having a correlation with depression and mental distress. They also found that individuals who lost their job due to natural disasters were more likely to be depressed.

1.3.3.5 Posttraumatic Stress

Looking at data from the Hurricane Katrina Community Advisory Group, researchers found posttraumatic stress and growth, as well as personal, spiritual, and social changes after trauma. This was looked at through the lens of race, poverty, and educational level (Rhodes and Tran 2012). The researchers focused on individuals who were identified as black, African American, or white. Researchers focused on these populations because they wanted to have a deeper understanding of how African Americans viewed the emergency response and the implications it had on well-being. They noted that even though everyone was affected by the hurricane and problems with emergency response, low-income African Americans were affected more significantly. In addition, low-income African Americans were more likely to see the problem as due to discrimination (Adams et al. 2006; Pew Research Center 2005; Sanders 2005; Sherman and Shapiro 2005).

1.3.3.6 Physical Health and Health Problems

After the Deepwater Horizon oil spill, according to the Gulf States Population Survey (GSPS), researchers found unemployed individuals and households with an annually income of $25,000 or less were associated with frequent, more than 14 days in the past month, mental and physical distress, as well as depression (Fan et al. 2015). According to the World Bank and GFDRR reports, across the globe, disasters affect people in poverty differently. Health is a major factor contributing to this difference. Following a disaster, poorer households must make decisions with long-term effects that households with higher incomes don't have to make as frequently, if at all (Hallegatte et al. 2017).

1.4 Case Studies of the Social and Economic Impact of Geo-Disasters

This section introduces several case studies of geo-disasters that created significant social impacts from the perspectives of social vulnerability and economic impact to the community.

1.4.1 Hurricane Katrina (Levee System Failure): New Orleans Case Study

In 2005, Hurricane Katrina caused flooding due to the levee-system failure creating significant social impacts to the community in New Orleans. Extensive studies have been conducted from different angels. This section presents a summary of in-depth literature review on how Hurricane Katrina affected people of low socioeconomic status.

Following Hurricane Katrina, Masozera et al. (2007) explored contributing elements of natural disaster vulnerability by examining how neighborhoods in New Orleans were differently impacted by Hurricane Katrina on the basis of pre-existing physical, economic, and social vulnerabilities. The researchers found that New Orleans districts with higher numbers of individuals in poverty had fewer individuals with flood insurance (Masozera et al. 2007). A positive correlation was also found between the proportion of residents who did not own vehicles and those that lived below the poverty level. This finding indicates that those living below the poverty line are less likely to have access to a crucial resource needed for evacuation.

1.4.1.1 During Disaster (from Perspectives of Damage, Evacuation)

A study explored the relationship between hurricane damages and income levels of varying areas around New Orleans (Masozera et al. 2007). The authors concluded that low-income parts of New Orleans did not experience more flooding than higher-income areas. However, they did find that almost 30% of people in areas with more damage, moderate to severe, were living in poverty compared to only about 25% in areas that has less damage, little to no damage (Logan 2006a, 2006b).

Thiede and Brown (2013) wrote a research paper about race and SES and how they intersect with evacuation behaviors during Hurricane Katrina. In reviewing research, they found that research concludes while SES and race are factors that do matter, where an individual lives, among other factors, matters just as much. Findings showed that Black people and individuals with less than a high school education were less likely to evacuate prior to a hurricane striking. This lack of evacuation has been attributed to not having adequate resources such as money, transportation, or shelter to successfully evacuate. Low-education respondents were more than twice as likely to be unable to evacuate when compared to respondents with some college education (Thiede and Brown 2013).

1.4.1.2 After Disaster (from the Perspective of Posttraumatic Stress)

Researchers examined posttraumatic stress and growth, as well as personal, spiritual, and social changes following Hurricane Katrina, using data from the Hurricane Katrina Community Advisory Group. This was looked at through the lens of race, poverty, and educational level (Rhodes and Tran 2012). The researchers focused on individuals who were identified as black, African American, or white. Researchers focused on these populations because they wanted to have a deeper understanding of how African Americans viewed the emergency response and the implications it had on well-being. They noted that even though everyone was affected by Hurricane Katrina and problems with emergency response, low-income African Americans were affected more significantly. In addition, low-income African Americans were more likely to see the problem as due to discrimination (Adams et al. 2006; Pew Research Center 2005; Sanders 2005; Sherman and Shapiro 2005) as cited in Rhodes and Tran (2012).

Low educational attainment was also a factor associated with low SES that Rhodes and Tran (2012) linked to increased posttraumatic growth 6 months after Hurricane Katrina. On the other hand, individuals living in poverty were linked to increased posttraumatic stress. However, posttraumatic growth and stress usually are experienced together. In fact, according to Rhodes and Tran, many clinicians believe in order to recover and adjust psychologically following trauma, one must have positive beliefs and understand the impact of trauma (Bonanno 2004; Herman 1992, 2015; Park and Ai 2006; Park and Helgeson 2006; Tang 2006). This is concerning, in the case of Hurricane Katrina survivors, because individuals in poverty had posttraumatic stress but didn't experience the posttraumatic growth needed for recovery and adjustment.

1.4.2 Socioeconomic Impacts of Haiti Earthquake

This case study presents the detailed observations and records on the social impact of the Haiti Earthquake by the social impact reconnaissance team during their visit to the site (Green and Miles 2011).

In January of 2010, Haiti was struck with a catastrophic earthquake near the metropolitan region of Port-au-Prince. The earthquake devastated Haiti, which is often cited as the poorest nation in the Western Hemisphere, resulting in over 200,000 deaths and the destruction of 30,000 commercial buildings and 250,000 residences. The direct damages and losses were estimated to be over $7.8 billion which was 120% of Haiti's gross domestic product in 2009 (GoH 2010). This case study summarizes a broad overview of the direct and indirect social impacts of the earthquake based on field reconnaissance done by the social impact reconnaissance team in March 2010 (Green and Miles 2011). During their visit to the site, the team made observations and conducted interviews focused on the impacts of the earthquake and recovery among a range of social groups across space and time. Two notable pre-disaster vulnerabilities were the focus of observation and data collection: access to and the provision of livelihood opportunities and shelter. Livelihood was defined by the researchers as the ability and opportunity of an individual, group, or organization to command resources to facilitate well-being (after Wisner et al.

(2004)). Therefore, livelihood includes access to basic services like education, health care, clean drinking water, and employment opportunities.

1.4.2.1 Shelter

The Haiti 2010 earthquake resulted in widespread and overwhelming damage to residential structures in the area. Low-income households tend to be more likely to experience extreme damages and displacement as a result of poor maintenance (Bates and Peacock 1987; Bolin and Bolton 1986). For households in this category, emergency shelters can become longer-term stays than expected or even permanent homes (Bolin 1994). It has been estimated that 105,000 homes were completely destroyed during the 2010 earthquake with another 208,000 homes being damaged which left over 10% of Haiti's population homeless (Government of the Republic of Haiti (GoH) 2010). Along with that, there was 20 million cubic yards of debris that was estimated to take over 2 years to remove (United Nations Development Programme (UNDP) 2010). After the earthquake, shelter ranged from simple makeshift tents out of sheets, tarps, and tin, to lumber frames with tarps. According to rapid housing assessments done, though residential damage was extensive, many individuals who were displaced left undamaged or slightly damaged homes. Many residents expressed fear of staying in their concrete homes after the earthquake out of concerns that an aftershock would cause their home to collapse. Some survivors interviewed reported that they did not want to return home because they wanted to continue accessing the disaster relief services. They expressed concern that moving back to their homes would result in them losing access to services and aid distribution points and ultimately becoming invisible to the government.

Several researchers found that residents in temporary shelters experience violence, isolation, and a heightened vulnerability to hazards (Enarson and Morrow 1997; Peacock et al. 2007). Interviews conducted with women staying in internally displaced persons (IDP) camps showed that a lack of lighting, overcrowding, insecure shelters, lack of policing inside the camps, loss of adult male family members, and unequal aid distribution were contributing factors to the widespread incidences of sexual assault and rape by gangs and armed individuals. Often times, victims were afraid to report the attacks out of fear of violent retaliation (Amnesty International 2011).

1.4.2.2 Impact on the Economy

There was a significant and immediate impact to Haiti's formal as well as informal economy. It was estimated that two-thirds of the economic activity in Haiti occurs in the capital region which also represents 85% of the government's revenue. Of the over USD $7 billion in damages after the earthquake, 70% of those losses were experienced by the private sector. Out of those direct losses, around 60% was damage to physical infrastructure and the remaining 40% was a result of economic loss. Between 2009 and 2010, Haiti's gross domestic product dropped by 5% (The World Bank 2011).

Interviews with Champ de Mars residents indicated that many of the country's professional and service workers were not employed because of damage to buildings, business closures, and injuries. An Oxfam-funded survey of 1700 individuals found that of those surveyed the most pressing need at the time was employment followed by schools (Yves Pierre 2010).

1.4.2.3 Impact on Education

Almost 50% of Haiti's total school and university population is located in the metropolitan region that was heavily damaged by the 2010 earthquake (Government of the Republic of Haiti (GoH) 2010). An estimated 38,000 students and over 1300 teachers were killed in the earthquake, which also destroyed the Ministry of Education building (Bakody and Van den Brule 2010). School assessments conducted by the Quest Department of Haiti in November 2010 indicated that 29% of schools were completely destroyed while another 52% were damaged (Carlson et al. 2011).

1.4.3 The Economic Loss due to Newcastle Earthquake

Earthquakes create not only social distress but also economic loss to the impacted community. This case study illustrates an example estimation of the economic loss from 1989 Newcastle earthquake, New South Wales, Australia (Deloitte. 2016, 2021).

Earthquakes have been found to not only cause social distress but also economic stress and loss in the impacted community. This case study provides an example estimation of the economic losses caused by the Newcastle earthquake, a 5.6 magnitude earthquake that struck near the town of Boolaroo on December 28, 1989. Boolaroo is located 15 km west of the Newcastle business district and 140 km north of Sydney. The Newcastle earthquake resulted in the loss of 13 lives and injuries of over 160 people making it the deadliest earthquake in Australia. Nine of the 13 deaths occurred as a result of the collapsing of the Newcastle Workers Club. Over 35,000 homes, 3000 buildings, and 147 schools were damaged in the earthquake (Young 2015).

The effects of the Newcastle earthquake were widespread and long lasting. During the peak of the crisis, around 400 people were provided with temporary accommodations. A month after the earthquake, the Disaster Welfare Recovery Center provided assistance to almost 14,000 people (Young 2015). The most severe damage however was around the Hamilton shopping center which had to remain closed for 6 weeks to prevent looting and keep the public safe from the damaged infrastructure. It was noted by Carr et al. (1997) that upwards of 70,000 insurance claims were made throughout one region following the earthquake; 10% of these claims pertained to damage to commercial properties. A study by Dobson et al. (1991) examined whether stress from the Newcastle earthquake led to an increased risk for heart attack and coronary death. It was found that there were six fatal heart attacks and/or coronary deaths 4 days following the earthquake, all occurring in individuals under the age of 70. This number was unusually high for this time of year; however, there was no evidence of an increase in heart-related health issues in the following 4 months.

When looking at the impact the earthquake had on mental health, it was found that 21% of the adult population in Newcastle had used the general support/disaster-related services available, while only 6% of adults used medical services available (Carr et al. 1997). An estimated 1.5% of the adult population was injured during the earthquake; however, only 0.4% required medical treatment as a result. It was also estimated that 28% of individuals who were highly exposed to the earthquake experienced moderate to severe psychological distress as a result. Six months following the earthquake, 18.3% of those who experienced high levels of threat were more likely to have suffered PTSD. Though the earthquake resulted in multiple failures in the electricity substations near the epicenter of the earthquake and shut down electricity for consumers, power was quickly restored within a few hours.

The lack of data on the impact of the Newcastle earthquake led to a top-down approach being applied to estimate intangible costs. The earthquake was estimated to cost $3.2 billion in insured losses according to the ICA database. Using an average intangible cost to insured multiplier of 2.4 and a tangible cost to insured losses multiplier of 2.2, the Newcastle earthquake was estimated to generate $10.2 billion in intangible costs and $8.5 billion in tangible costs. This resulted in a total economic cost of over $18 billion in 2015 dollars.

1.4.4 Sinkholes

Sinkholes can be a terrifying and even life-threatening event for homeowners that can result in significant socioeconomic losses due to the high costs of housing repair in conjunction with insurance prices negatively responding. This section presents multiple cases showing social vulnerability in sinkhole disasters.

Populations that are particularly vulnerable can experience mental and financial difficulties with long-term consequences that can lead to poverty and mental distress. However, Moshodi et al. (2016) found that government involvement is minimal. They found when reviewing the current status of stakeholder management in the Merafong Local Municipality (MLM) in South Africa, there was a lack of systematic risk management being done and a low level of communication about these risks between local and community governments. Similarly, in the state of Florida, sinkhole coverage through one's insurance would be the only solution homeowners have available. It is important to note that it is extremely rare for academic efforts to go towards investigating the impacts of sinkholes on a socioeconomic level;

therefore, the literature review was focused on case studies that focused on the socioeconomic consequences of the event.

In Tampa, Florida, a man was tragically swallowed into a sinkhole while he was sleeping in his home one night in February 2013. Family members reported "going through hell" following the loss of their family member. Two years later, in the same location, the sinkhole reopened with a diameter of 20 feet. It is clear that the sinkhole risk is a permanent issue in this area, even though the site had been repaired. This resulted in community-wide impacts such as dropped housing prices and increased insurance premiums for those living there.

Another example of these unexpected sinkholes happened in 2020 when a sinkhole with a 100-ft diameter opened up in Westmoreland, a neighborhood in Gainesville, Florida. As a result, six families were evacuated and two houses had to be torn down. A month after the evacuation, one of the families had an interview with WCJB-TV and said that "seeing and hearing the sinkhole has been terrifying" (Bellofatto 2020). They went on to say that initially the city said they would "provide the financials and take on the role of investigating the sinkhole." However, the city later told the family that they would not be doing that and the responsibility was on the family. This process costs upwards of tens of thousands of dollars, which the homeowners could not afford. The homeowner stated "We can't move back in here... we just can't. We put so much work into this house... and to lose it this way... I'm terrified. I am completely terrified."

Though it seems that the negative socioeconomic consequences of sinkholes are very apparent, many people still may not be aware of the risk until it is too late. Individuals belonging to a vulnerable group (i.e., low-income, low-education, differently abled individuals) may be at a higher risk with less awareness and preparation which can greatly impact their post-disaster resiliency and ability to recover.

Additionally, sinkhole risk and events significantly impact housing insurance and real estate markets. Sinkhole risk exposure can be costly to homeowners due to sinkhole insurance costing three times more than other insurance with a typical deductible around 10% of the home's value (Harrington 2014). To further complicate the issue, the Florida Senate (applicable since July 2016) recently passed new legislation that made sinkhole insurance even less accessible (The 2021 Florida Statutes 2020). The law agrees that the insurance company can decline coverage if sinkhole activity is present within a certain distance of the property. During an interview, Mark Stewart, a professor of Geology at the University of Southern Florida, stated that in order to get a mortgage, one must have homeowners insurance and that the difficulty to get insurance in sinkhole areas causes banks to be "very hesitant to give mortgages and that would greatly affect property values" (Devitt 2013). The current trend is not to blacklist the areas that are likely to be impacted by sinkholes but to instead leave the risk to homeowners. Though homeowner's insurance in Florida covers sinkholes, it does not cover other causes of subsidence.

Typically, insurance companies will have a geotechnical consultant do an investigation. Many times, when the consultants diagnose the damages to a homes, they say that the damages are not the result of a sudden sinkhole. This usually causes the homeowners to hire their own geotechnical consultant which results in the issue going to arbitration. Being that there are geotechnical experts on both sides, there cannot be a determination of whether it is a sinkhole or not. Based on a comprehensive literature review and the authors' knowledge, there is no clear assessment guidance or criteria for determining the occurrence of a sinkhole, which compromises the level of professionalism and reliability. As a result of this, a lot of money is left to be made by geotechnical firms, lawyers, and insurance agencies, all at the cost of the homeowner.

1.5 Discussion on Differential Impacts of Geohazards in Social Vulnerability

This section looks at the variation of social vulnerability for different geohazards. The authors realized that a limited number of studies exist in specific geohazards; thus, expanded to general natural disasters as well, but within the context of geo-related cases.

We examined whether the meaning of social vulnerability comes from the various investigations focusing on geohazards with different driving factors, different timescales, or different stages of disaster cycle. This approach (variation of social vulnerability) can be based from physical science and risk-based view of vulnerability. Barroca et al. (2006) indicated that the hazard itself has a significant influence, viewing social vulnerability in this way by stating, "vulnerability is the susceptibility to degradation or damage from adverse factors or influences." Tapsell et al. (2010) also pointed out the importance of technocentric viewpoint, stating that the "etiology" of the geohazard can strongly affect the vulnerability to that hazard.

Understanding geohazards has shifted over the years; hazards are no longer viewed as "acts of God" or solely being caused by a social structure problem (Faulkner and Ball 2007). The causes of hazards can be viewed much clearer now with scientific and engineering understanding, particularly from the views of geology, hydrogeology, geomechanics, soil-structure interaction, etc. For example, different hazards have different spatial and temporal shapes that allow for them to be monitored, modeled, predicted, and managed (e.g., evacuation and mitigation) before the hazard occurs (Alexander 1993, 2000). From this perspective, multiple researchers have explored the distribution of each hazard and their condition, human occupancy of the hazard location, and degree of loss post-hazard for that specific disaster event (Messner and Meyer 2006; Rygel et al. 2006; Simpson and Human 2008).

Another perspective is that social vulnerability meaning and inclusionary size for differing groups (e.g., individuals, communities, and social systems) can vary depending on how a specific geohazard takes place and impacts those varied groups. The level of impact of a specific geohazard and its influence area may also vary; for example, floods due to extreme rainfall events or earthquakes/tsunami impact much larger areas than a landslide or sinkhole that involve smaller areas of influence.

One can hypothesize that anxiety and perceived vulnerability probably vary with generation mode, rate of onset, velocity, area the hazard is affecting, and timing of the hazard (Tapsell et al. 2010). Table 1.1 shows the variations in these etiological characteristics of different hazards and sets the scene for various empirical examples. Tapsell et al. (2010) have shown the etiological characteristics of hurricane and different types of floods. Based on his summary, the authors have added other types of geohazards that include landslide, earthquake, sinkhole, and subsidence (see Table 1.1) For example, it is understood that different geohazards can have different leading times. For instance, floods can have long lead times because we can predict the path and anticipate the level of damage depending on category; however, earthquakes and sinkholes have a much shorter time with little to no prediction and preparedness. Information like this helps disaster managers decide whether to set up a weather service for longer time scales or set up a warning system for shorter time scales. This kind of problem also arises after the disaster has struck, both immediately after the disaster and long term. Communities and residents can also be prepared in different ways and modes through the cycles of preparedness, responses, recovery, and mitigation.

Tapsell et al. (2010) also pointed out that the different risk environments and risk cultures should also be looked at in further detail. Looking at risk cultures and environments helps us understand the social vulnerability on a national, local, and cultural level and also how this is related to specific/different types of geohazards. One example is the structural quality of housing as a major factor in determining the vulnerability to most geohazards but doesn't have the same significance for other natural hazards (e.g., droughts, heat, etc.). Another example is how an individual's background (e.g., social, educational, cultural, etc.), including their occupation, can make someone more or less vulnerable to things like loss or being insured. An individual's backgrounds/occupation can make them vulnerable to some things but resilient for other things; this makes effective emergency management more difficult and is one area that needs further research (Buckle et al. 2000).

1.6 Conclusion and Recommendation

We have conducted a comprehensive literature review on societal impacts as a result of geohazards, particularly to low socioeconomic status (SES) group. Specifically, we explored and summarized failure mechanisms and characteristics of different geohazard types, procedure and mechanism of socioeconomic impact of those disasters, and case studies describing the level of impact and how different SES groups suffered from disasters. According to our comprehensive literature review, it is obvious that people of lower SES are less prepared for disasters and suffered more.

The followings are the summary of key findings: (1) people of low SES may not always afford expensive preparedness actions, such as purchasing flood or earthquake insurance or making home improvements to increase resilience in certain types of disasters, (2) people of low SES may be less likely to evacuate in response to

Table 1.1 Etiological characteristics of hazards that may affect social vulnerability

	Etiology of climatically-driven hazard	Hurricanes	Pluvial floods	Fluvial flood-large basins	Fluvial flood-small basins	Landslide	Earth-quake	Sink hole	Subsidence
Generation mode (where):	Source of hazard geographically distinct from receptor	X		X	X	X	X		
	Source and receptor undifferentiated		X					X	X
Rate of onset (how fast):	Rapid		X		X	X	X	X	
	Slow	X		X					X
Flow-out characteristic:	Systematic, focused, predictable, and slow			X					
	Geographically and temporally diffuse and slow								X
	Chaotic and rapid	X	X		X	X	X	X	
Area affected (how large):	Point, focused	X	X		X	X		X	
	Diffuse			X			X		X
Persistence (how long):	Long	X		X					X
	Short		X		X	X	X	X	

disaster warnings, even though many factors influence evacuation behavior, and when people of low SES do not evacuate in response to warnings, it may be because they are unable to do so; (3) people of low SES are more likely to live in housing that is vulnerable to geo-disasters, as well as live in areas where risks from disasters are higher; (4) people of low SES face many barriers in receiving aid to help them rebuild their homes and meet their other needs; and (5) people of lower SES after a disaster may be more likely to experience distress and depression.

It can be argued that social vulnerability varies with the etiology of individual hazards, but this has yet to be fully explored in the literature. The literature also indicates that social vulnerabilities may change between the different stages of the disaster cycle, and that people can move in and out of vulnerability depending upon their position in the cycle. Importantly, the literature suggests that risk and vulnerability need to be examined within the wider context, in particular the social conditions in which risk-exposed people live, think, and make choices.

It is suggested that qualitative approaches to vulnerability assessment need to be considered more frequently in order to better understand the processes and relationships contributing to social vulnerability.

Although no universal catalogue of vulnerability indicators are present, the social vulnerability measurement should measure correct/accurate information at the right scale, with suitable conceptual underpinning. Therefore, the mechanism and characteristics of different geohazard types should be pre-understood, particularly temporal and spatial changes. The authors agree with the point made by Birkmann et al. (2013), suggesting the identification of a basic generic framework for vulnerability, for example, by linking key components such as exposure, susceptibility, and coping, with additional elements that reflect a specific geohazard.

As a future step, incorporating anthropology into understanding risk assessment and recovery from geohazard disasters will be highly recommended. It has been debated if a disaster is an objectively identifiable phenomenon and if a disaster can be defined solely as a set of physical impacts (as discussed above) or socially constructed perceptions (Oliver-Smith and Hoffman 1999). Since anthropology as a discipline analyzes the phenomenon holistically and comparatively, it is well suited to view how social, cultural, economic, political, and environmental factors interrelated with each other (Henry 2005). Furthermore, anthropology of disaster takes complicated interactions into consideration such as the degree of local conflict of cooperation, the differential abilities of response stemming from gender, ethnicity, socioeconomic status, and age (Das 1997). It is recommended that more ethnographic research should be conducted to gain deeper understanding of disaster relief agencies' cultures and constraints (Henry 2005). Understanding how external social and environmental relations along with the internal economic and social structure allow for adaptation to employ knowledge in order to reduce disaster vulnerability and damage becomes vital (Oliver-Smith and Hoffman 1999). Exploring the social vulnerability against geohazards is a relatively understudied topic, and engaging in anthropological empirical studies will be highly beneficial.

Based on extensive literature review and discussions, the authors recommend that social vulnerability properly measured over the disaster cycle, needs to be incorporated into geohazard risk assessment and disaster management in which traditional approaches are technological and single-discipline based.

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