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Here comes the rain: Assessing storm hazards vulnerability in Northeast Ohio

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ABSTRACT

The frequency and intensity of coastal storm events in the Great Lakes region, USA is predicted to increase in the coming decades, exposing at-risk populations to potential hazards including flooding, erosion, and combined sewer overflows. In response, applied research is needed to identify communities that are most vulnerable to storm hazards, and to support municipal officials and local residents with building capacity for resilience. This study analyzes the storm hazards vulnerability of 42 communities that are located within the Northeast Ohio Regional Sewer District (NEORSD), including the city of Cleveland and its inner and outer ring suburbs. Communities are ranked against each other for vulnerability according to a social and environmental indicator, each of which is comprised of five variables that operationalize the sociodemographic and biophysical challenges facing local populations. The indicators are combined to produce a composite Storm Hazards Vulnerability Index (SHVI). Results suggest that the most environmentally vulnerable communities are not always home to the most socially vulnerable populations. Overall storm hazards vulnerability correlates more closely with the environmental indicator than the social, especially among the most vulnerable communities.

1. Introduction

Coastal storms and resulting flood events have historically been the most destructive natural hazards in northeast Ohio in the USA. According to the Cuyahoga County, OH Natural Hazards Mitigation Plan (2011) [18], storms and heavy rains are responsible for 9 of the past 11 presidential declarations of disaster in the county resulting in over $650 million in damages from 1950 to 2010.

Climatic changes are predicted to worsen these hazards by producing increased precipitation and more frequent and severe storm events [2]. The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) [38] indicates that these storms have the potential to cause problems for existing urban water infrastructure and can be detrimental to water systems in North America.

Rising atmospheric temperatures lead to increased water temperatures, which contributes to the formation of such storms. Most importantly, climate change is increasing the number of the most extreme storm events that can cause flooding, erosion, and excess runoff. In fact, in the Great Lakes region, some climate models predict that by mid-century precipitation in 50-year storms (storms that have a 1 in 50 chance of occurring in any given year) may increase up to 29% from historic levels [19].

For some communities in northeast Ohio, the physical and economic impact of storm hazards are particularly difficult to absorb due to a lack of institutional resources (personnel, financial and technical resources) and large percentage of low-income home and business owners. Residents can be at risk due to environmental factors, such as proximity of housing structures to flood zones, as well as sociodemographic challenges that make recovering from coastal storms more difficult. This is especially true in many of the inner ring suburbs of the city of Cleveland, where urban blight and shrinking tax bases have left municipal governments strained for resources.

In response, applied research is needed to identify communities that are increasingly vulnerable to storm hazards, and to support municipal officials and local residents with building capacity for resilience. This study attempts to accomplish this goal by analyzing the storm hazards vulnerability of 42 communities that are located entirely within the Northeast Ohio Regional Sewer District (NEORSD), including the city of Cleveland and its inner and outer ring suburbs.

Communities are categorized for vulnerability according to a social and environmental indicator, each of which is comprised of five variables that operationalize the sociodemographic and biophysical challenges facing local populations. The social and environmental indicators are combined to produce a Storm Hazards Vulnerability Index (SHVI), which allows evaluation of trends across variables as well as a measure of overall vulnerability. The SHVI can help inform decision-making regarding storm hazard mitigation and emergency management preparedness strategies in the most vulnerable communities in the

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region.

In the sections that follow are a brief background on the evolution of theory related to vulnerability studies, the methodology, results of the analysis, discussion of the implications of this work, and a conclusion including limitations and guidance on further research needs.

2. Theory

The emphasis of this project aligns directly with the second stated recommendation of the Cuyahoga County, OH Natural Hazards Mitigation Plan (2011) [18] – "Develop strategies and priorities to mitigate risk from natural hazards and identify action steps or projects to reduce the risk." Risk and vulnerability are different, yet related concepts for our purposes. Following Clark et al. [8] and an earlier review of vulnerability studies by Dow [20], *vulnerability* is defined as a population's inability to "deal with hazards, based on the position of groups and individuals within both the physical and social worlds." These authors and others in the field suggest *vulnerability* equates to the potential for loss [10]. *Risk*, according to Clark et al. [8], is related to exposure, or the likelihood of experiencing hazardous events. The ultimate goal of this research is to consider both the physical and social risks facing 42 communities in northeast Ohio, and how they combine to predict the vulnerability of place.

The idea of vulnerability as a social product grew out of debate over existing paradigms that tried to describe society's relationship to natural hazards. For example, attempts to incorporate psychological tests into development fieldwork helped define the hazard perception paradigm, but were ultimately dismissed when it became clear that different people simply perceived natural hazards differently [43]. It was also suggested that "Social, economic, and political conditions were required to turn the hazard into a disaster" ([43], pg. 6). Race, ethnicity, gender, and economic status appeared to play a role in how different groups of people were impacted by natural hazards. Previous concepts including the perception paradigm and the hazard-focused paradigm were ultimately replaced by a vulnerability paradigm that focused on specific constraints and threats facing individual populations (Blaikie et al., 1994; [43]).

More recent studies on vulnerability to natural hazards have emerged from equally disparate formulas, as reviewed in detail elsewhere [1,10,20,43]. Although 'potential for loss' is a common theme there are often several competing perspectives on vulnerability. One approach considers vulnerability simply as the potential exposure to physical hazards, while another accepts exposure to hazards as given and instead explores the social construction of vulnerability among individuals or communities [44]. Building on a robust catalog of studies investigating vulnerability, Cutter [10] offered a third path coined the 'hazards of place' model of vulnerability. This approach takes into account both environmental factors and social response within a defined geographical area.

In the twenty years since the inception of the hazards of place framework, researchers have found it useful to analyze how people are affected by and respond to coastal storm hazards, particularly given the increasing risk of communities to more frequent and severe storms. The hazards of place methodology along with various adaptations has been used to assess the vulnerability of several east coast communities to sea-level rise, extreme coastal storms, storm surges, and to develop a social vulnerability index for coastal flooding and climate adaptation planning [32,39,44,8].

While much work has been done on hazards of place and coastal storms, there are relatively few studies within this field that focus on the Great Lakes region. The National Oceanic and Atmospheric Administration (NOAA) [34] released a pair of pilot studies on "Economic Assessment of Green Infrastructure Strategies for Climate Change Adaptation" in the Great Lakes Region in 2014 that offer related examples from Duluth, MN and Toledo, OH. Similarly, Noordyk and Harrison [35] conducted a needs assessment survey for the NOAA Great Lakes Coastal Storms Program on "Great Lakes Planning and Mitigation Needs for Coastal Storm Hazards."

Among Great Lakes states, Ohio faces specific challenges in terms of vulnerability. In urban areas, historically unprecedented warming trends are projected by the end of the 21st century [26]. These areas, where population density is high, a majority of residents are minorities, and a large percentage of households live below the poverty threshold, have exhibited increased social vulnerability in other states [15]. Communities in rural Ohio are also vulnerable to changes in extreme weather, given the large percentage of the state's economy that is dependent on agriculture [26]. Spring flooding in particular poses a risk to Ohio's agricultural industry and the livelihoods of agrarian populations.

In northeast Ohio's largest city of Cleveland, social conditions and land use patterns are suggested to magnify the impact of climate change, including frequency and intensity of coastal storms. The Cleveland Climate Resiliency and Urban Opportunity Plan indicates that urban sprawl and an overall decline in population has led to concentrated poverty in urban neighborhoods, redundant infrastructure, and growing economic and racial stressors [9], all of which can impact the vulnerability of local populations.

2.1. *Developing a storm hazards vulnerability index (SHVI)*

2.1.1. *Social vulnerability*

Within the field of social vulnerability several factors are generally accepted as being influential. These include, "lack of access to resources (including information, knowledge, and technology); limited access to political power and representation; social capital, including social networks and connections; beliefs and customs; building stock and age; frail and physically limited individuals; and type and density of infrastructure and lifelines" ([14], pg. 245).

Some researchers have sought to go beyond these broad themes and focus on the social construction of vulnerability [21,3,8]. Such studies suggest that a wide variety of socio-demographic indicators can increase vulnerability, many of which can be extracted from U.S. Census Bureau data (see [14]).

Recent efforts have sought to summarize our understanding of social vulnerability to natural hazards in different locations and at different scales. Tapsell et al. [40] published a report that examines social vulnerability in relation to natural hazards in Europe. Dwyer et al. [23] quantified social vulnerability to natural hazards in Australia. Cutter and Finch [15] summarized changes in social vulnerability to natural hazards in the United States with the goal of better informing emergency management response. Some scholars have also updated earlier assessments, like Blaikie et al. [3] who released a second edition after 15 years of their seminal text on the relationship among natural hazards, people's vulnerability and natural disasters, highlighting important findings since the publication of the original version.

Others have zeroed in on the construction of social vulnerability within certain populations or in response to specific biophysical events. Susan Cutter [11] revisited decades-old research on vulnerability among women to highlight how social transformations like increasing wealth gaps, large-scale population movements, and violence against females impact the environmental burdens on women and children. Another recent effort by Cutter [12] looks at the social vulnerability of food supply chains in the face of natural disaster. Others have employed GIS techniques as a tool for mapping social vulnerability to natural hazards [27], such as seismic hazards in Italy [28,5]. Some have looked more specifically at social vulnerability of storm-related hazards, including Koks et al. [31], who investigated the social vulnerability of flood risk management in the Netherlands, and Fekete [25], who developed a social vulnerability index for river floods in Germany.

2.1.2. *Environmental vulnerability*

Historically, measures related to environmental vulnerability have