

Cumulative Health Impacts of Cascading Environmental Hazards on Rural Communities

Project Summary/Abstract

The overarching goal of this project is to identify and mitigate the cumulative mental and physical health impacts of cascading environmental hazards on rural communities facing significant health challenges. These communities are disproportionately affected by cascading hazards due to limited resources and lack of infrastructure. Focusing on Lake County, California, the project aims to quantify these cumulative health impacts of cascading hazards, including chemical (e.g., air and water pollution) and non-chemical stressors (e.g., disaster-driven losses, social disruption). The project outcomes empower informed decision-making to improve the health and resilience of rural communities facing significant health challenges exacerbated by environmental cascading hazards.

The project has three specific aims. First, it will assess how cascading hazards increase chemical and non-chemical stressors in rural communities, using the Community Capitals Framework (CCF) to classify community vulnerabilities. Second, it will quantify the cumulative health impacts of stressors from cascading environmental hazards in rural communities by developing a coupled systems model using historical health data, community health surveys, and geospatial analysis. Third, with community input, we will co-develop the **Health Resilience Evaluation and Adaptation to Cascading Hazards (H-REACH)** index—a novel decision-support tool for guiding resource allocation and intervention strategies during cascading hazards. The effectiveness of the HRCHI will be tested using Agent-Based Modeling (ABM) and Deep Reinforcement Learning (DRL) to simulate resource distribution. We will also create an interactive web platform to support decision-makers and educate rural communities with real-time projections based on the most up to date-data.

This project will fill critical gaps in understanding how cascading environmental hazards impact the mental and physical health of rural communities by leveraging partnerships with academic researchers, community leaders, local stakeholders, and residents. Using cutting-edge methodologies, this project will provide actionable insights for policy interventions and resource allocation to improve health outcomes and build resilience to cascading environmental hazards in vulnerable populations. The outcomes are directly aligned with the NIH's mission to promote community health and reduce the adverse effects of environmental hazards on rural communities.

This research will enhance the scientific understanding of cascading hazards and their health impacts. It will also deliver practical tools and strategies for public health agencies, policymakers, and communities to adapt and thrive under a changing environment.

Project Narrative

More than 29 million Americans live in areas with a significant potential for extreme environmental events (e.g., heat waves, wildfires), which can result in a host of cascading environmental hazards that trigger chemical (e.g., air and water pollution) and non-chemical stressors (e.g., environmental hazards-driven losses, social disruption): 12 million of these people are considered “socially vulnerable” [1]. This transdisciplinary multi-institution project addresses the adverse health consequences of cascading environmental hazards on rural communities by investigating how hazard-driven chemical and non-chemical stressors exacerbate mental and physical health risks in these populations. The project will develop the **Health Resilience to Cascading Hazards Index (HRCHI)** to guide policy interventions and resource allocation during wildfire and other extreme weather events to improve resilience in vulnerable communities.

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Specific Aims: The lifetime risk of exposure to cascading environmental hazards (e.g., wildfires, heat waves) will rise in this century [2], posing a serious threat to human health and wellbeing [3-5]. The direct impacts of the rising number of environmental hazards have been known for years, including increases in morbidity and mortality from cardiovascular, respiratory, and infectious diseases [6,7]. These cascading environmental hazards are collective traumas that pose a serious threat to mental and physical health globally [8,9], especially when people experience cumulative exposures over time [10]. However, state of the art research has not addressed the cumulative mental and physical health impacts of the increased rate of exposure to cascading environmental hazards. Not only do these cascading hazards have immediate effects on mental health [11,12] and physical safety, but they can also affect mental and physical health overtime through ongoing displacement and increased exposure to chemical stressors including pollutants and contaminants in air and water. These health threats are more pronounced in rural communities with pre-existing barriers including geographic isolation, limited access to health care, and socioeconomic hardships. The overarching **goal** of this multidisciplinary project is to mitigate the cumulative mental and physical health impacts of cascading environmental hazards on rural communities facing significant health challenges. The urgency is undeniable, with over 29 million Americans living in areas at high risk for extreme wildfires and related cascading hazards [1].

Methods: Our study will be conducted in Lake County, CA, a rural region characterized by poor health, exacerbating patterns of cascading environmental hazards, and a large vulnerable population. Using satellite images, publicly available environmental data, local weather station data, and data from Lake County and California Department of Public Health, we will monitor, track, and document the exposure rates for environmental hazards retrospectively and as they occur. Working closely with our community partners, we will conduct focus groups and a longitudinal survey of Lake County residents to identify the county's healthcare priorities. The survey study will include a representative panel of ~2000 residents who will complete four waves of surveys assessing exposure rates to cascading environmental hazards, mental and physical health (BSI, National Health Interview Survey), risk perceptions, and disaster preparedness. Using advanced computational modeling, time series analyses, and epidemiological methods, we examine links between the increasing rate of cascading environmental hazards-driven chemical stressors, including air pollutants (e.g., PM2.5) and water contaminants (e.g., nutrients leading to algal blooms) and non-chemical (i.e., hazard-driven losses) stressors and human health at both the individual and county levels. We will then develop the **Health Resilience Evaluation and Adaptation to Cascading Hazards Index (H-REACH)** and a decision-making platform to optimize resource allocation in response to cascading hazards and train community partners and policymakers in its use.

Aim 1: Characterize how cascading environmental hazards (e.g., heat waves, wildfires) increase the rate of exposure to chemical (e.g., PM2.5, algal blooms) and non-chemical (e.g., losses) stressors in rural communities facing significant health challenges.

Hypothesis: The rate of exposure to chemical and non-chemical stressors linked to cascading environmental hazards will increase over time in the rural communities of Lake County, CA.

Aim 2: Characterize trends in mental and physical health ailments in rural communities and examine their link with exposures to environmental hazard-driven chemical and non-chemical stressors.

Hypothesis: Accelerating exposure rates to chemical and non-chemical stressors driven by cascading environmental hazards will be linked to increases in mental and physical health problems (e.g., CVD, heat stroke, asthma).

Aim 3: Use predictive models capturing the expected temporal and spatial patterns of hazard-driven health outcomes to develop the H-REACH and decision-making platform for resource allocation and educate Lake County policymakers in its use.

Hypothesis: Compared to existing decision-making methods, the use of H-REACH in the decision-making platform will enable targeted, actionable interventions that may improve mental/physical health outcomes (e.g., lower rates of PTSD, chronic disease) in rural communities facing significant health challenges.

Expected Results: The project findings will advance cutting-edge science about the health effects of cascading environmental hazards in rural communities by characterizing the chemical and non-chemical stressors linked with exposure to cascading hazards; characterizing mental/physical health correlates of escalating rates of chemical and non-chemical stressors driven by cascading environmental hazards. Our research—facilitated by our close partnership with affected communities—will nurture the development of science-informed, community-based solutions for residents and local decision-makers as they cope with the health impacts of a changing environment and serve as a model for other rural communities nationally.