International Cartographic Association
Association Cartographique Internationale

Mapping the geographically and temporally evolved flood risks in the contiguous United States

Joynal Abedin[a,*]

[a] *Texas A&M University, College Station, TX-77843, USA. Joynal Abedin – j.abedin@tamu.edu*

* Corresponding author

Keywords: Flood Risk, Flood Exposure, Vulnerability, Spatial Analysis, Temporal Analysis

Abstract:

Flooding is one of the most recurrent and costliest natural disasters that have led to significant fatalities and economic losses worldwide. Due to climate change, floods have become more devastating and frequent in recent years, and the trend is projected to continue, posting additional challenges to human communities. Therefore, efforts to assess and reduce flood risk are of great societal significance and have attracted the attention of governments, researchers, and the public. Extracting baseline information on flood risk and its temporal evolution is essential to formulate flood risk reduction strategies. According to the Intergovernmental Panel on Climate Change (IPCC), flood risk is defined as the product of flood hazard, flood exposure, and vulnerability and can be minimized by lessening any of the three components.

Despite the robust literature on flood risk assessment in the United States, four research gaps necessitate further investigations. First, prior studies in the United States have investigated the three elements (flood hazard, exposure, and vulnerability) separately, but flood risk research considering all three factors is rare. Second, previous research initiatives emphasized the spatial aspects of flood exposure and risk in the United States and overlooked the temporal variations. Third, earlier studies on flood hazards considered only 100-year flood zones and disregarded the 500-year floodplains in the United States. Fourth, previous studies poorly quantified the impacts of the driving factors of human development in flood zones that shape flood exposures and risks, e.g., flood experiences, flood damages, and urban-rural disparities. As the Federal Emergency Management Agency (FEMA) has vastly updated flood maps over the past few years, it is crucial to analyze the latest flood maps to generate a solid understanding of the geographically and temporally evolved risks brought by flood hazards for successful and cost-effective flood risk reduction.

The objective of the study is to evaluate and map county-wise flood risk in the United States and unravel its spatial-temporal dynamics from 2001 to 2019 to answer the following research questions. First, what proportions of the population and developed areas are at risk of 100-year and 500-year flood hazards in the United States? Second, how flood risk in the United States has changed over time? Third, how do communities' sensitivity to flooding risk vary based on the driving factors of flood zone development, such as population density and demographics, economic development, land use patterns, flood occurrences, and flood damages? Fourth, what are the possible solutions to mitigate future flood risk under climate change scenarios? Three associated hypotheses are examined: 1) the expansion of human settlements in flood zones had continuously declined across the contiguous United States from 2001 to 2019; 2) communities experiencing more flood occurrences and damages were more responsive to floods by avoiding development in flood zones than communities with fewer flood experiences and impacts; 3) well-urbanized communities were more sensitive to floods with decelerated development in flood zones than rural communities.

The main datasets used in this research are national land cover data from USGS, FEMA 100-year and 500-year flood maps, Spatial Hazard Events and Losses Database for the United States (SHELDUS) historical flood frequencies and damages data, population and rural-urban classifications data from US Census, and NASA Socioeconomic Data and Applications Center (SEDAC) vulnerability data. All the datasets are downscaled into 30-meter pixel levels.

The first step to estimate flood risk is to evaluate flood exposure (Figure 1), the proportion of developed areas and population in the flood zone for each county in the United States. Land cover maps of 2001, 2011, and 2019 are reclassified into ‘developed’ and ‘non-developed’ categories and overlaid with the 100-year and 500-year flood zone maps. The differences between developed areas in flood zones for three different years are evaluated to elucidate the temporal changes. Furthermore, populations in flood zones are interpolated using the geographically weighted regression (GWR) based on the spatial distributions of developed areas. To assess the spatial flood risk scenario, Local Moran’s I for each county in the United States is estimated (Figure 2).

Abstracts of the International Cartographic Association, 6, 2, 2023.
31st International Cartographic Conference (ICC 2023), 13–18 August 2023, Cape Town, South Africa.
https://doi.org/10.5194/ica-abs-6-2-2023

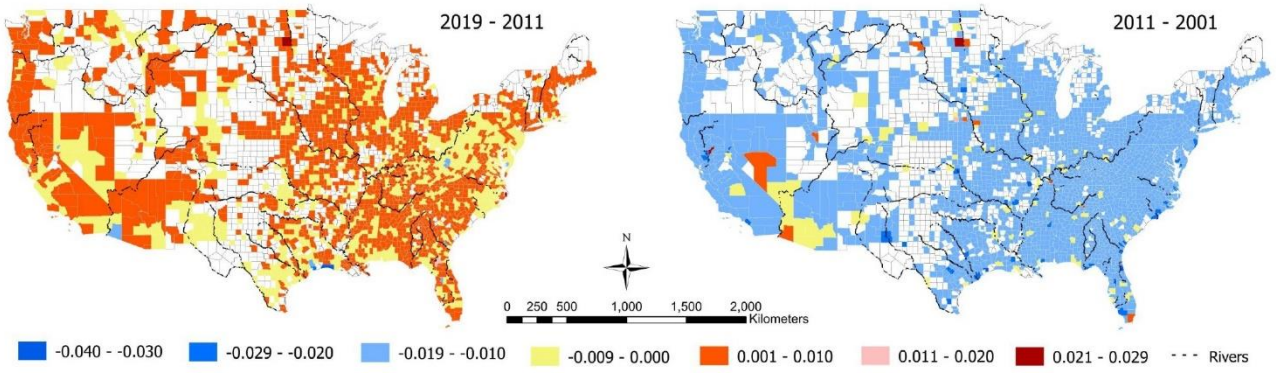

Figure 1: Changes in the proportion of developed areas in flood zones from 2001-2019

To determine the disparities in the urban-rural communities' sensitivity to high flood risk, the rural-urban classification data with developed areas in flood zones for three different times are overlaid. The proportion of developed areas in flood zones is assessed with the proportion of total land that is lying in flood zones to reveal the county's sensitivity and responsiveness to development in flood zones.

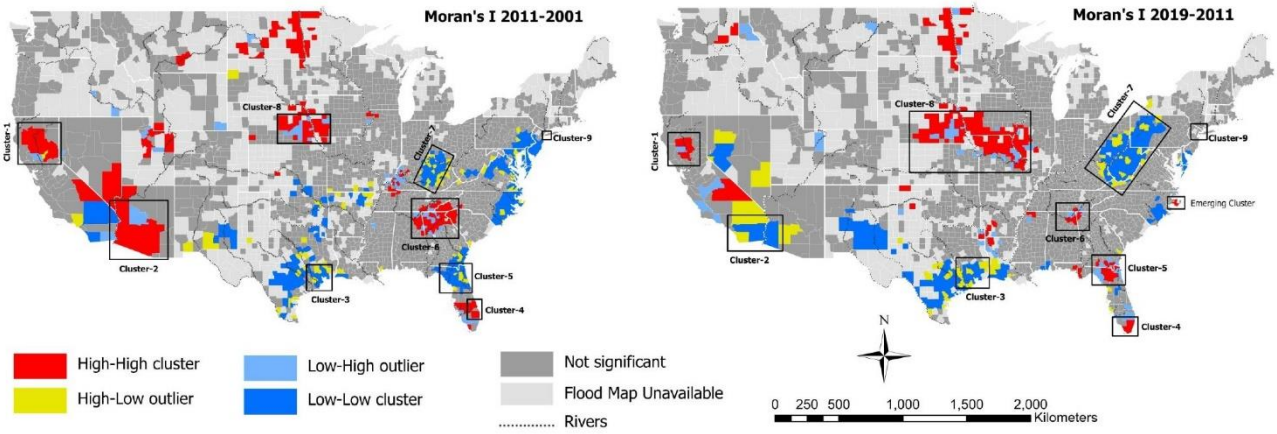

Figure 2: Clusters of local Moran's I from 2011-2001 and 2019-2011

Finally, we calculate the flood risk (FR) using equation 1. The hazard (H) dimension denotes the 100-year and 500-year flood layers. The developed areas and populations exposed to 100-year and 500-year flood zone represent exposure (E). The SEDAC vulnerability index approximates flood vulnerability (V) with a value ranging from 0-1.

$$\text{Flood Risk (FR)} = \text{Hazard (H)} * \text{Exposure (E)} * \text{Vulnerability (V)} \quad \text{..... (1)}$$

This study will provide an in-depth knowledge of the county-based spatial and temporal patterns of flood risk in the United States with significant implications in formulating essential flood risk reduction strategies, improving flood mitigation policy, and developing adaptation approaches. First, the study will develop a national comprehensive database on localized flood risks and their changes at the county level in the United States. It will identify areas with high flood risks, so that policymakers can provide recommendations for strategies to reduce flood risk, such as improving flood protection infrastructure, implementing land use policies that limit development in flood-prone areas, and providing education and outreach to communities about how to prepare for and respond to floods. Second, the study will detect emerging, growing, and disappearing high flood-risk zones in the US which will benefit insurance companies to better understand the risks associated with different locations and adjust their coverage accordingly. This could lead to more accurate and fair pricing of flood insurance policies. Finally, the study will reveal the temporal variations of flood risk in the United States that will facilitate the evaluation of the effectiveness of flood risk management strategies in reducing flood risk and protecting communities from the impacts of flooding. Follow-up research can target on simulating future flood risks in the United States based on projected land use/cover and population growth datasets under different climate change and planning scenarios.

Abstracts of the International Cartographic Association, 6, 2, 2023.
31st International Cartographic Conference (ICC 2023), 13–18 August 2023, Cape Town, South Africa.
https://doi.org/10.5194/ica-abs-6-2-2023 | © Author(s) 2023. CC BY 4.0 License.