Extreme Precipitation-induced Concurrent Disasters Risk Assessment through Socio-economic and Topographic Vulnerability

Raviraj Dave[1], Srikrishnan Siva Subramanian[1], and Udit Bhatia[1]

[1]Indian Institute of Technology Gandhinagar

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Abstract

The warming climate intensifies the frequency and intensity of extreme precipitation events, leading to increases in precipitation-induced disasters. Precipitation-induced disasters such as flooding, landslide, and debris flow possess the potential risk of damage to socio-economic activity. The losses due to concurrent hazards in a region not only depend on the intensity and frequency but also socio-economic condition, topography, and exposure to the affected region. Recent advancements in risk mapping have shown approaches to measure the vulnerability to disaster but not accounting for concurrent hazards can lead to underestimation of risk. Here we propose the framework to assess the risk of concurrent precipitation-induced disasters while incorporating socio-economic, topographic, and land use information. In Kerala, India, the Periyar river basin is selected as a testbed for analysis considering 2018 extreme precipitation events. We perform 2D hydrodynamic flood inundation modeling to analyze the spread of the flood with the Spatio-temporal simulations of shallow landslides and debris flows using infinite slope-based stability and erosion models to identify the exposure of disaster. We evaluate socio-economic vulnerability and topographic vulnerability using disparate techniques from census demographic data and digital elevation model data respectively and exposure using land use information. The risk mapping is performed at the taluka (sub-district) level in the Periyar basin. Our results show better land-use planning considering multi-hazard vulnerability assessments reduces the exposed risk and would be beneficial for risk mitigation measures in high-risk areas

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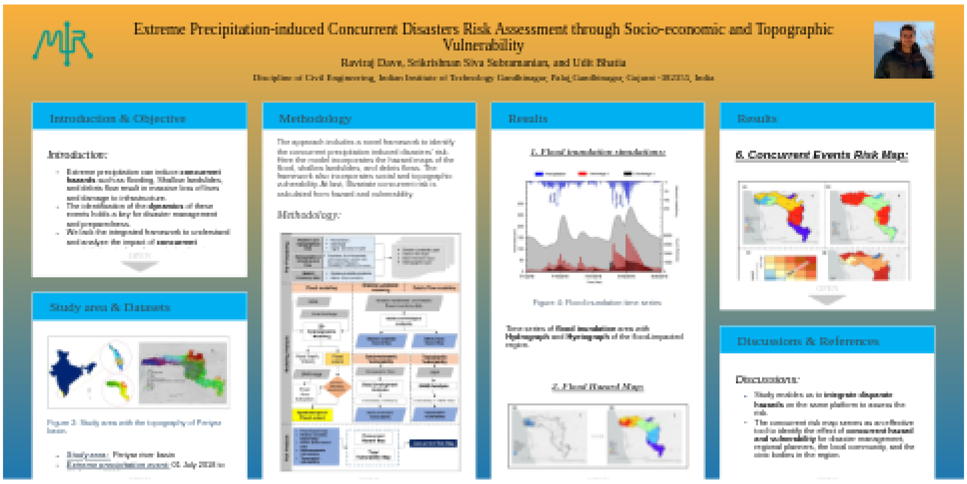

Raviraj Dave, Srikrishnan Siva Subramanian, and Udit Bhatia

Discipline of Civil Engineering, Indian Institute of Technology Gandhinagar, Palaj,Gandhinagar, Gujarat -382355, India

  

PRESENTED AT:

INTRODUCTION & OBJECTIVE

Introduction:

- Extreme precipitation can induce **concurrent hazards** such as flooding, Shallow landslides, and debris flow result in massive loss of lives and damage to infrastructure.
- The identification of the **dynamics** of these events holds a key for disaster management and preparedness.
- We lack the integrated framework to understand and analyze the impact of **concurrent precipitation-induced events**, leading to underestimating risk.

Objective:

- To develop an **integrated framework** to identify the **concurrent risk** of extreme precipitation induced multi-hazard while understanding **community** and **topographys'** influence.

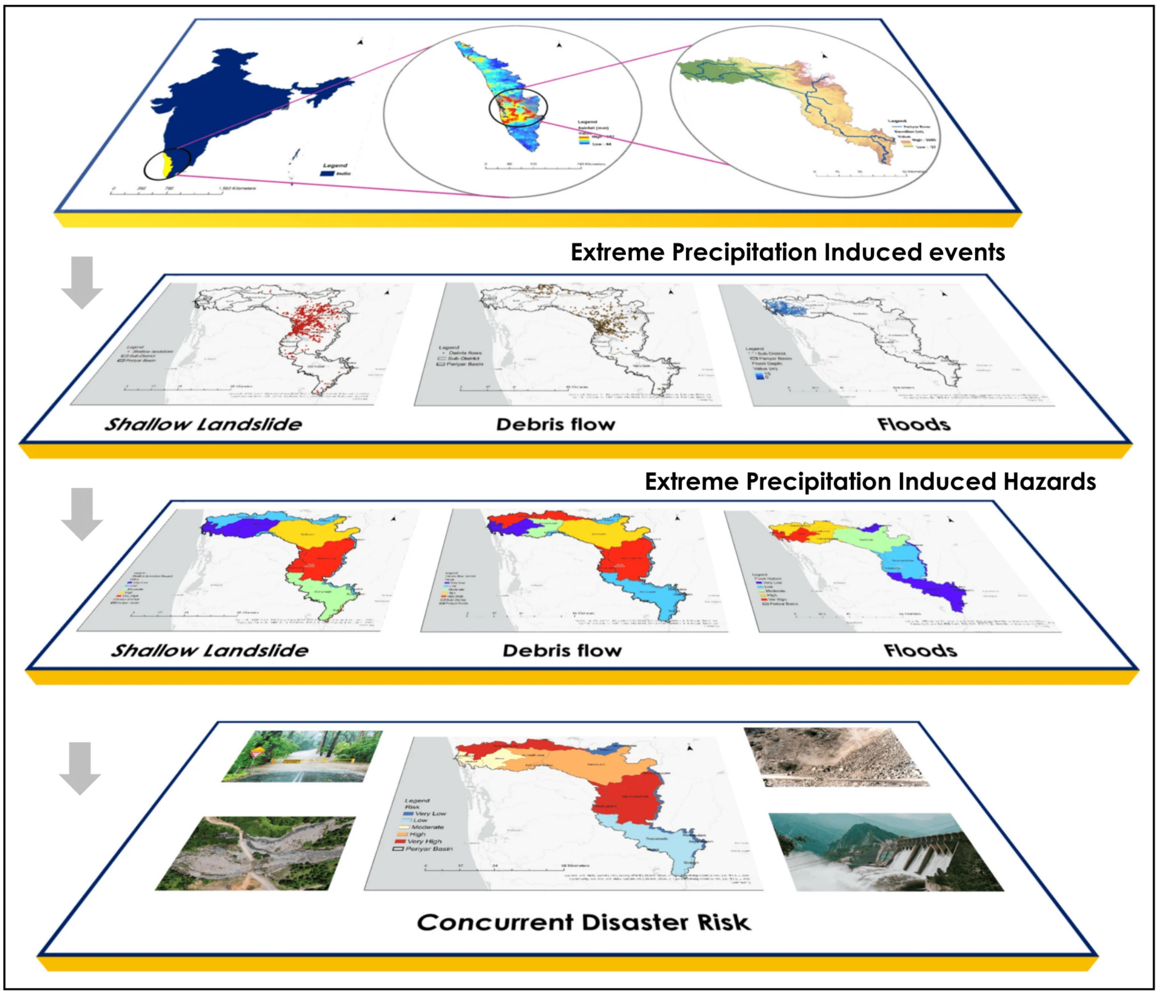

Figure 1: Conceptual figure of framework

STUDY AREA & DATASETS

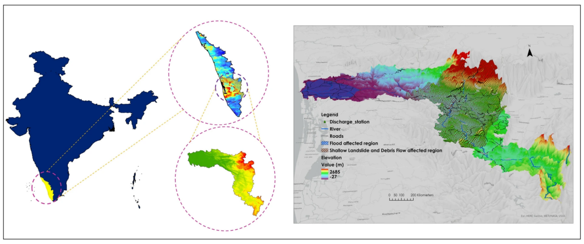

Figure 2: Study area with the topography of Periyar basin.

- ***Study area:*** Periyar river basin
- ***Extreme precipitation event:*** 01 July 2018 to 31 August 2018
- ***Basin characteristics:*** Longest river in Kerala, 244 km stretch with a 5398 sq. km. catchment area
- ***Damage of extreme event:*** 5.4 million people, 440 casualties, cost of damage USD 53 billion, and extreme damage to infrastructure.

Datasets:

- ***Demographic data:*** Census of India 2011
- ***Shallow landslides and Debris flows inventory data:*** Hao et al. 2020
- ***Elevation data:*** Shuttle Radar Topography Mission (SRTM)
- ***Meteorological data:*** India Meteorological Department (IMD)
- ***Hydrological data:*** India WRIS
- ***Remote sensing data:*** Sentinel-1 (SAR Data)

METHODOLOGY

The approach includes a novel framework to identify the concurrent precipitation induced disasters' risk. Here the model incorporates the hazard maps of the flood, shallow landslides, and debris flows. The framework also incorporates social and topographic vulnerability. At last, Bivariate concurrent risk is calculated from hazard and vulnerability.

Methodology:

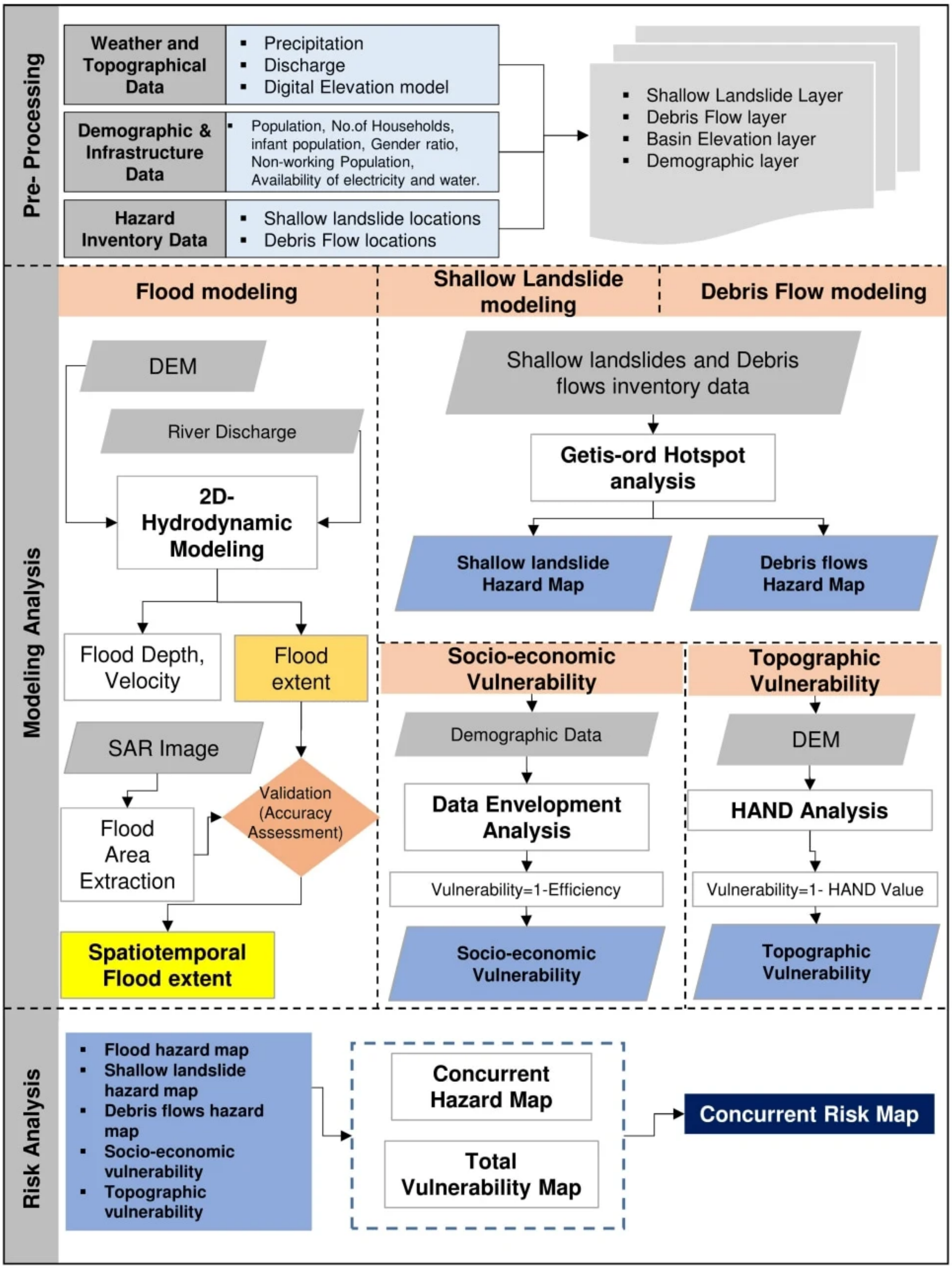

Figure 3: Overview of the framework

RESULTS

1. Flood inundation simulations:

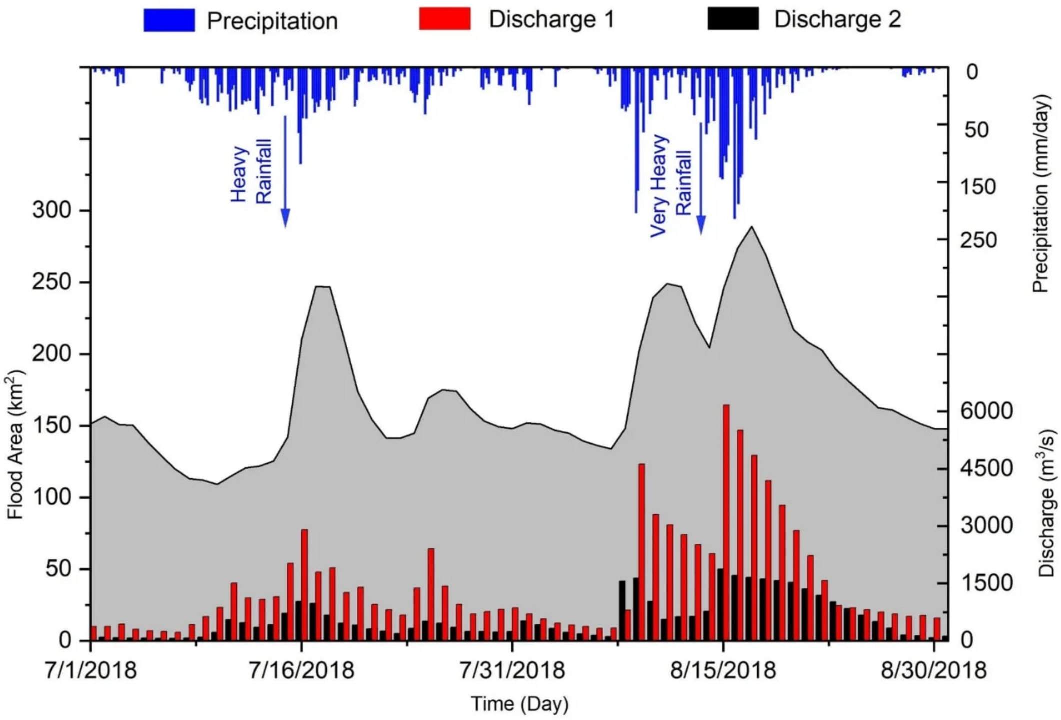

Figure 4: Flood inundation time series

Time series of **flood inundation** area with **Hydrograph** and **Hyetograph** of the flood-impacted region.

2. Flood Hazard Map:

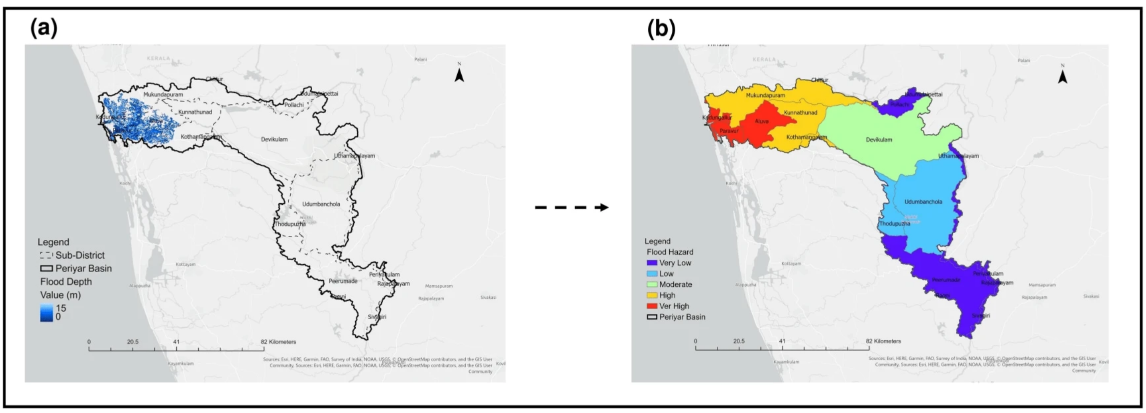

Figure 5: Flood hazard map

A flood hazard map is generated from a **Flood inundation** map. (a) Represents the extent and **depth of the maximum flood** inundation, (b) The **flood hazard** map is categorized into five disparate classes.

3. Shallow landslides Hazard Map:

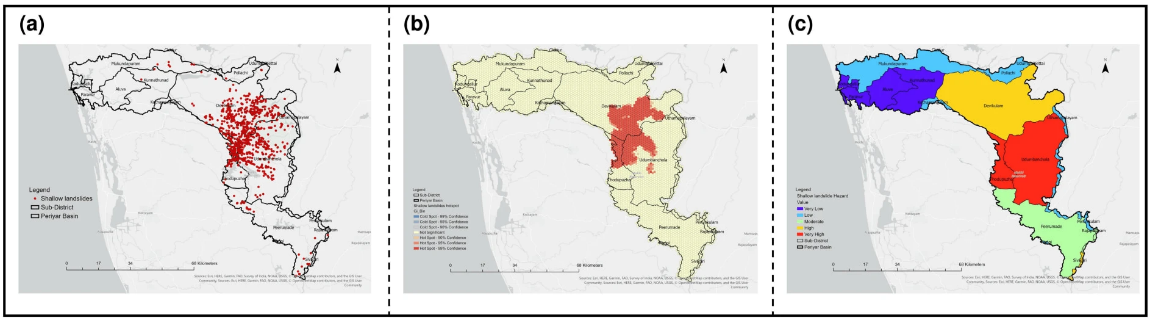

Figure 6: Shallow landslides hazard map

(a) Representing the **shallow landslides** events in the basin, (b) The **Getis-ord Hotspot** map representing the clustering of events, and (c) Shallow landslides map generated using the **weighted average** method and categorized in five disparate classes based on severity.

4. Debris flows Hazard Map:

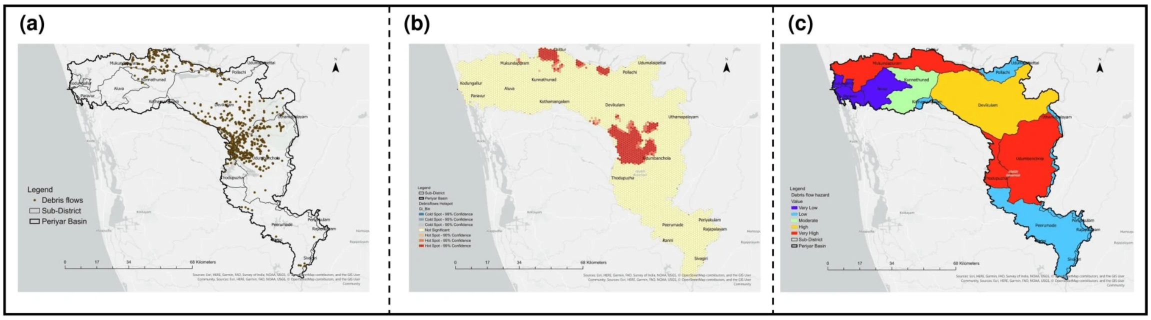

Figure 7: Debris flows hazard map

(a) Representing the **Debris flow events** in the basin, (b) The **Getis-ord Hotspot** map representing the clustering of events, and (c) Debris flow map generated using the **weighted average** method and categorized in five disparate classes based on severity.

5. Socio-economic and Topographic Vulnerability:

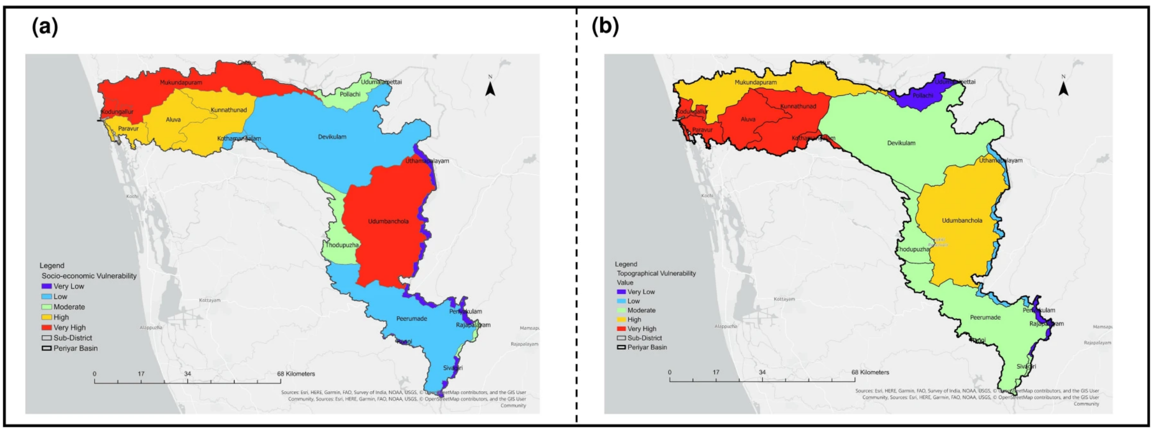

Figure 8: Socio-economic and topographic vulnerability map

(a) Socio-economic Vulnerability computed from **Data Envelopment Analysis (DEA)** method and (b) Topographic Vulnerability computed from **Height Above the Nearest Drainage (HAND)** method.

RESULTS

6. Concurrent Events Risk Map:

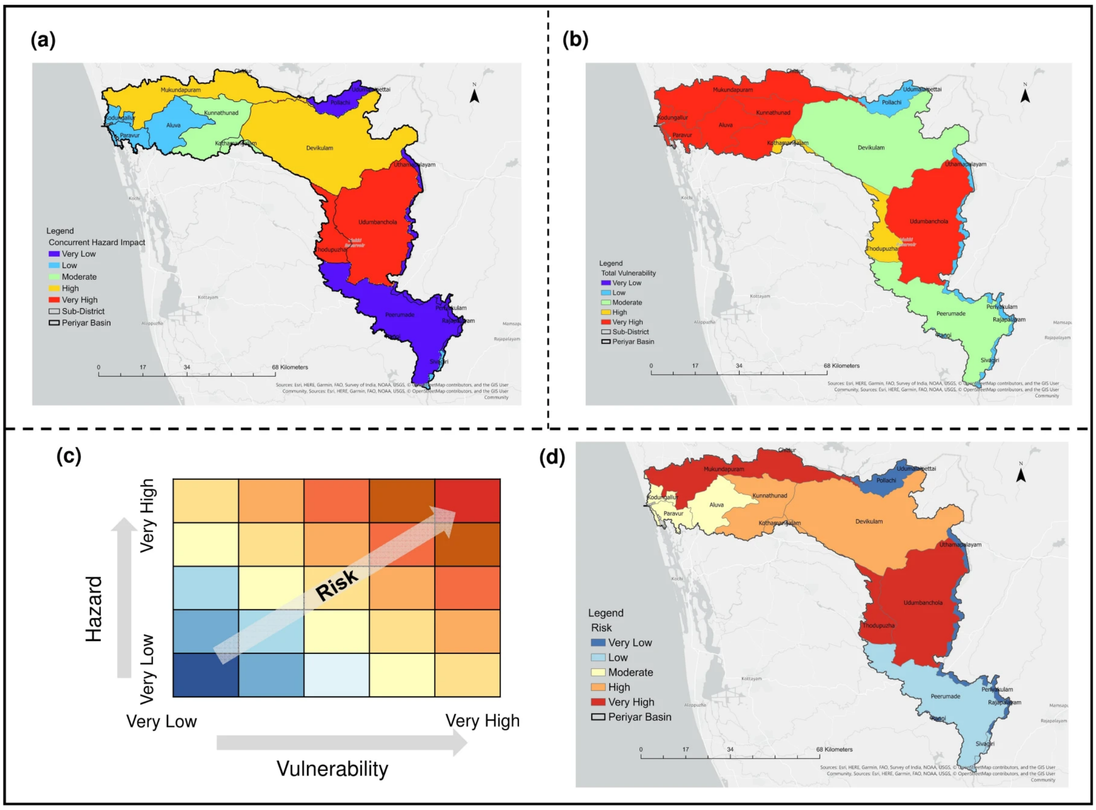

Figure 9: Concurrent events risk map

(a) Concurrent Hazard Map, (b) Total Vulnerability, (c) matrix representation of **risk calculation**, and (d) Concurrent events Risk map.

DISCUSSIONS & REFERENCES

Discussions:

- Study enables us to **integrate disparate hazards** on the same platform to assess the risk.
- The concurrent risk map serves as an effective tool to identify the effect of **concurrent hazard and vulnerability** for disaster management, regional planners, the local community, and the civic bodies in the region.

References:

- Dave, R., Subramanian, S.S. and Bhatia, U., 2021. Extreme precipitation induced concurrent events trigger prolonged disruptions in regional road networks. Environmental Research Letters
- Mohanty, M. P., Vittal, H., Yadav, V., Ghosh, S., Rao, G. S. & Karmakar, S. (2020), `A new bivariate risk classifier for flood management considering hazard and socio-economic dimensions', Journal of environmental management 255, 109.

AUTHOR INFORMATION

* Discpline of Civil Engineering, Indian Institute of Technology Gandhinagar, Palaj, Gandhinagar, Gujarat -382355, India

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