

Understanding Human-Flood Interactions: Sociohydrological Perspectives on Flood Impacts and Safe Development Paradox

Abstract

We have irrevocably entered the era of Anthropocene, a geological epoch where human activity is the dominant driver of environmental change. In this epoch, the hydrological cycle is no longer governed by physical phenomena but is increasingly shaped by human interventions, land-use transformations, and societal decisions. Despite significant advancements in hydraulic engineering and flood forecasting, global flood losses continue to escalate, revealing a "safety paradox", where structural protection can lead to increased long-term damage. This dissertation challenges the traditional hazard-centric paradigm of flood risk management, arguing that operational flood risk models fail to capture the complex feedback between hydrological extremes and human systems. Adopting a socio-hydrological perspective, the research employs a multi-scale and multi-contextual strategy, combining data-rich empirical modelling in Germany with large-scale spatial analysis and agent-based modelling in India. The study first addresses the lack of specificity in flash flood damage assessment by developing FLEMOflash, a probabilistic multivariate loss model for the commercial sector. Using machine learning and Bayesian networks on post-disaster survey data from Germany, the research identifies key drivers of damage beyond water depth and demonstrates the significance of emergency measures in mitigating direct tangible losses. Shifting focus to the human dimension of flood impact in the Global South, the thesis introduces a novel framework for assessing human impacts across the Indian subcontinent. By utilizing unsupervised machine learning and spatial regression, the analysis reveals distinct hotspots of vulnerability and identifies the "adaptation effect" in frequently flooded basins, where communities exhibit increased resilience through social learning from frequent flood exposure. Furthermore, the research provides rare empirical evidence of the levee effect in the agrarian Brahmaputra floodplain. Combining satellite-derived land-use data with census records, the study uncovers a proximity paradox. While embankments stabilize physical assets and agricultural retention in the immediate 0-1 km zone behind defences, they are simultaneously associated with increased marginal workforce. This suggests a decoupling between asset protection and livelihood security. Finally, these empirical insights are synthesized into a dynamic geospatial agent-based model (ABM) that simulates the long-term co-evolution of flood exposure and adaptive-migration. By incorporating social heterogeneity through distinct behavioural archetypes, the model demonstrates that structural protection creates differentiated risk trajectories. The simulations reveal that while wealthier, mobile groups may face "surprise" risks due to climate change-induced elevated hazards, marginalized populations often become trapped in high-risk zones due to structural immobility rather than a lack of awareness. Overall, this dissertation establishes that flood risk is an emergent property of coupled human-water systems. The findings underscore the critical need to transition from static hazard and vulnerability mapping to dynamic, equity-sensitive risk management strategies that account for behavioural feedback, social inequality, and the unintended consequences of infrastructure in a changing climate.