Flood Resilient Scenario Modelling (FReSMo): for assessing coastal flood impact of built infrastructure

Coastlines have played an instrumental role in the progression of human settlement due to various economic and ecological benefits. However, the rapidly changing climate is foreboding for both coasts and coastal settlements. Coastal extremes like tidal anomalies and storm surges are becoming more frequent, damaging built infrastructure and jeopardising coastal sustainability. Ninety-two percent of the world population under the severe threat of the 100-year flood lives in South and East Asia, mostly in China (329 million) and India (225 million). Developing nations with increased mean sea levels, a high density of marginalized populations near the coastline, and inadequate capacities for mitigating flood risk are suffering from negative consequences of climate change. About 95% of India's climatic extremes occur along its 7500-kilometer coastline consisting of 3288 fishing communities. However, such marginal communities cannot move since they depend on coastal regions for revenue. Thus, climate change adaptation is beneficial for resilient regional development. Recurring floods would destroy the local economy without a climate-resilient policy.

India's National Action Plan for Climate Change (NAPCC) has associated the loss of residential structures as the primary impact of prolonged flooding, affecting coastal welfare. Cyclones Bulbul (2019), Aamphan (2020), and Yaas (2021) destroyed 3.44 million dwelling units in affected districts of West Bengal. Despite the loss, coastal flood impacts on buildings are rarely prioritised in developing countries due to their resource-intensive nature, lack of aboriginal damage catalogues or damage records, and discrete behaviour based on building typology, which prevents the adaptation of foreign damage curves on native buildings. Investing in flood-resilient housing requires calculating flood damage costs for economic assessments and optimum resource allocation for Building Back Better (BBB). Thus, this research seeks to prove Flood Resilient Scenario Modelling (FReSMo), an innovative method for designing realistic flood resilience solutions in impoverished nations.

The current research examines an analysis, understanding, and solution-based methodology. During the analysis phase, the thesis had to identify and comprehend the risk profile of Sagar Island, West Bengal, India. In eight years, the island's built-up class has increased from 1.7% to 3.6%. (2012–2020). The area under water rose from 6.6 to 8.6%, indicating clear evidence of a coastline breach. 72 percent of households on the island are semi-permanent, with a low rate of literacy and infrastructural connection, making them extremely sensitive to flood risk. The regional hazard and vulnerability maps provide the overall risk map. The findings reveal the dominance of economic and accessibility parameters in defining vulnerability, which will increase further due to changes in climate, population, and landscape dynamics.

The second part is to understand the flood behaviour of prominent building typologies in Sagar Island through a self-designed multivariate damage matrix. In the literature-based approach, the damage behaviour of mud buildings is predicted using logical assumptions based on the available scientific evidence. The laboratory-based technique examines flood effect via real-time exposure in an experimental scenario. A "multivariate damage matrix" represents flood depth and duration-related losses. It estimates damage stage variation using Monte Carlo simulations of synthetic flood data, showing its adaptability in spatio-temporal (flood character and intensity) applications.

The final portion of the thesis recognises IPCC-defined Nature Based Solutions as the best possible local adaptation method for flood-resilient development in developing nations. Each key of Source – Pathway – Receptor – Consequence incorporates dynamic flood risk assessment. The flood return period and relative sea level rise simulate the coastal flood exposure following a high tide occurrence. Peak over Threshold with Generalized Extreme Value calculates the flood return period. Using population, physiographic, socio-demographic, and economic characteristics, FUTURES (FUTure Urban-Regional Environment Simulation) model predicts 2050 built-up expansion. The integration of flood exposure and built-up provides a picture of the probable damage in each scenario. Finally, the flexible multivariate damage model interprets the financial loss from the damaged building. The loss estimates are used to calculate the cost-benefit ratio of mangroves in terms of reducing building vulnerability and protecting coastal sustainability. A 100m mangrove patch along the perimeter reduced building damage costs by 70% for 48-hour flooding and 75% for 24-hour flooding. Thus, FReSMo provides a comprehensive approach for disaster-related research in developing countries that goes beyond regional risk assessment. Scenario-based impact assessment using the new damage matrix idea gives FreSMo a repeatable diagnostic viewpoint for comparable items at risk. Finally, DRR investments' cost-effectiveness can be proven post-disaster, making them unmatched.

***Keywords*:** Climate change, Coastal flood risk, Cost-benefit analysis, Flood damage matrix, Flood return period, Nature Based Solution, Sea level rise.

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