

INTEGRATION OF CLIMATE-INFORMED FLOOD HAZARD MODELLING AND COMMUNITY PERCEPTIONS FOR ADAPTIVE FLOOD RISK MANAGEMENT IN THE MAHA OYA RIVER BASIN, SRI LANKA

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Abstract

The Maha Oya River Basin (MORB) in Sri Lanka experiences recurring floods threatening more than one million residents. However, flood management has traditionally emphasised physical hazard assessment, with limited integration of climate projections and community risk perceptions. This study develops a climate-informed flood hazard modelling framework and examines how exposure to hazard maps influences community risk perception, trust, and adaptive intent. Historical rainfall observations from four stations were quality-controlled, and bias-corrected CNRM-CM6-1-HR projections under SSP1-2.6 and SSP5-8.5 characterised future extreme rainfall. Gumbel frequency analysis and intensity-duration-frequency relationships generated 50-year design storms for historical and near-, mid-, and far-future periods, with the mid-future period selected as the critical period for both SSP1-2.6 and SSP5-8.5. HEC-HMS 4.13 and 2D HEC-RAS 6.6 generated flood hazard maps, achieving an accuracy of 0.92 and bias score of 0.99 during calibration against the May 2016 flood, and 0.83 and 1.42 during validation against the November 2025 flood. Simulated inundated area was 41.72 km² historically, rising to 51.26 km² (+22.86%) under SSP1-2.6 and 46.00 km² (+10.25%) under SSP5-8.5. Six flood-prone GN divisions in Pannala and Divulapitiya were identified, and 40 households within mapped inundation zones were purposively surveyed, giving a 97.6% response rate. Following exposure to the hazard maps, 87.5% of respondents reported improved understanding of flood risk, 85% reported increased concern about future flooding, and 97.5% expressed willingness to adopt adaptation measures. These findings highlight the potential value of integrating climate-informed hydrological and hydrodynamic modelling with participatory risk communication to improve risk awareness and support adaptive flood-risk management in the MORB.

Keywords: Climate change adaptation, CMIP6 projection, Hydrodynamic modelling, Risk perception, Participatory assessment

1. Introduction

Floods are among the most frequent and destructive natural hazards worldwide, and climate change may alter extreme precipitation and associated flood risks in coming decades [1]. In Sri Lanka, flood studies have generally focused on physical and topographic drivers of flooding, while comparatively less attention has been given to integrating future climate projections with community perspectives and risk perception. This creates a need for approaches that connect quantitatively modelled future flood hazards with the perceptions and adaptive intentions of affected communities.

The MORB supports more than one million residents and supplies water to fourteen water supply schemes. It has been classified as a high-stress basin because of its critical role in water supply and its vulnerability to climate change [2]. Areas such as Giriulla and Pannala regularly experience overbank flooding, while the November 2025 Ditwah flood event remains

prominent in the recent experience of affected communities. Prior MORB studies have focused primarily on low-flow conditions and domestic water security under climate change [3], whereas future flood hazards and their relationships with community risk perception remain comparatively underexplored.

Communities in hazard-prone areas often rely on past experience and local knowledge when preparing for floods; however, historical patterns may no longer adequately represent future risks under a changing climate. Hydrological and hydrodynamic models incorporating climate projections provide a scientific basis for assessing future flood scenarios, yet a persistent gap remains between technically derived hazard information and the perceptions, priorities, and adaptive capacities of affected communities. This study addresses that gap by developing climate-informed flood hazard maps for the MORB and evaluating how exposure to these maps influences community risk awareness, trust in scientific information, and willingness to adopt adaptive measures. The objectives of this study were to: (i) develop and validate a hydrological model for the MORB; (ii) simulate historical and selected future flood inundation under SSP1-2.6 and SSP5-8.5; and (iii) assess household flood experience, risk perception, understanding of model-derived flood-hazard information, and willingness to adopt adaptation measures.

2. Methodology

This study develops an integrated hydrological–hydrodynamic and community risk-perception framework for the MORB, which has a catchment area of 1,168 km², to link climate-informed flood hazard projections with community-level risk perceptions. Observed daily rainfall from four gauging stations (Ambepussa, Andigama, Aranayaka, and Eraminigolla; obtained from the Department of Irrigation) was subjected to missing-data analysis and consistency checks. The station rainfall data were subsequently converted to basin average rainfall using the Thiessen polygon method. Future precipitation was obtained from the CNRM-CM6-1-HR CMIP6 model (Copernicus Climate Data Store) for the historical period (2005–2014) and under SSP1-2.6 and SSP5-8.5 scenarios (2030–2100). The model precipitation was bias-corrected using quantile mapping. CNRM-CM6-1-HR was selected due to its high-resolution configuration and reported suitability for representing monsoon variability over Sri Lanka [4]. A single global climate model (GCM) was used to avoid potential smoothing of flood-peak magnitude and timing associated with ensemble averaging [5]. Extreme rainfall was characterised using Gumbel distribution fitting and intensity–duration–frequency (IDF) relationships to generate 50-year design storms for historical and near-, mid-, and far-future periods. The 50-year rainfall intensity was compared across these periods under both scenarios, and the mid-future period was selected as the critical period for subsequent HEC-HMS and HEC-RAS simulations.

HEC-HMS 4.13 was used to simulate rainfall-runoff processes. The model was calibrated against the December 2012 flood event and validated against the May 2016 event using streamflow records from the Giriulla gauging station. Simulated discharge hydrographs were subsequently used as inflow to a 2D HEC-RAS 6.6 model built on a 2 m resolution digital elevation model (DEM) with a 30 m × 30 m computational grid. The hydraulic model was calibrated against the observed inundation extent of the May 2016 flood and independently validated using the November 2025 flood event. Spatial model performance was evaluated using hits, misses, false alarms, correct negatives, accuracy, and bias score. Based on the flood-depth maps, six flood-prone GN divisions in Pannala and Divulapitiya DS Divisions were selected. A structured questionnaire survey was conducted among 40 households. The survey assessed demographic characteristics, past flood experience, trust in government agencies and scientific information, and flood risk perception before and after respondents were exposed to the model-derived flood hazard maps.

3. Results and Discussion

The quantile-mapping procedure substantially reduced the systematic bias in CMIP6 precipitation data. The resulting PBIAS values ranged from -0.327% to -0.328% across all four stations, indicating close agreement between bias-corrected model precipitation and observations. The hydrological model achieved a Nash–Sutcliffe efficiency (NSE) of 0.913 and a percent bias (PBIAS) of 8.67% during calibration, and an NSE of 0.866 and a PBIAS of 18.78% during validation, indicating good model performance. The coupled hydraulic model calibration produced close spatial agreement with the observed May 2016 inundation, yielding an overall accuracy of 0.92 and a bias score of 0.99, and, for the validation event (November 2025 flood), an accuracy of 0.83 and a bias score of 1.42. The historical scenario produced an inundated area of 41.72 km², increasing to 51.26 km² (+22.86%) under SSP1-2.6 and 46.00 km² (+10.25%) under SSP5-8.5 for the selected mid-future condition.

The household survey ($n = 40$) found that 75% of respondents had personally experienced flooding, most intensely recalling the 2025 event, and that 73% received no warning before past floods. Baseline trust in government agencies was very low for 85% of respondents, and expert-generated flood maps were viewed with suspicion before exposure. However, after viewing the hazard maps, 85% reported increased concern about future flooding, 87.5% indicated an improved understanding of local flood risk, and 97.5% felt authorities should take more action. In addition, 97.5% expressed willingness to adopt adaptation measures. Among respondents who selected specific adaptation options, 92.3% preferred flood insurance, 76.9% selected early warning systems, and 51.3% selected flood-protection structures. These results indicate that, despite low institutional trust, visual exposure to climate-informed hazard information can meaningfully shift risk perception and adaptive intent, supporting the case for coupling technical model development with participatory hazard communication.

4. Conclusions

This study found that the simulated future flood extent in the MORB increased under both climate scenarios for the selected mid-future condition, with the larger increase occurring under SSP1-2.6. The surveyed communities showed low institutional trust and limited preparedness, while exposure to flood-hazard maps was associated with improved risk understanding and greater willingness to adopt adaptive measures. These findings highlight the value of combining climate-informed flood-hazard information with community-based risk communication to support adaptive flood-risk management in the basin.

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