

FUTURE STREAMFLOW DYNAMICS IN THE MAHA OYA BASIN: INSIGHTS FROM MULTI-MODEL ENSEMBLES AND HYDROLOGICAL MODELLING

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This study applies a refined multi-model ensemble (MME) approach to reduce uncertainties in climate impact projections on river flow for Sri Lanka's Maha Oya River Basin. This vital water source faces escalating threats from climate change, which intensifies floods and droughts and stresses water management systems. Traditional single-model projections often fail to capture the basin's climatic heterogeneity, particularly its complex monsoon dynamics. To address this, the study applies five Coupled Model Intercomparison Project Phase 6 (CMIP6) Global Climate Models (GCMs)—MPI-ESM1-2-LR, CNRM-CM6-1, MRI-ESM2-0, ACCESS-ESM1-5, and HadGEM3-GC31-LL—under Shared Socioeconomic Pathways SSP2-4.5 and SSP5-8.5. A refined Reliability Ensemble Averaging (REA) method was developed, outperforming simple averaging (SA) by incorporating weighting factors from mean (W_1), standard deviation (W_2), the Standardised Precipitation Index (SPI-3) (W_3), and extreme percentiles (95th & 5th) (W_4 & W_5) of 3-month precipitation values.

Statistical downscaling was performed using the Long Ashton Research Station Weather Generator (LARS-WG) to bridge the spatial resolution gap between GCM outputs and the basin's requirements. Hydrological modelling was then performed with the Hydrologic Engineering Centre – Hydrologic Modelling System (HEC-HMS), calibrated (2003–2005) and validated (2006–2008) against observed streamflow from the Giriulla station. The model showed strong performance (Nash-Sutcliffe Efficiency (NSE) > 0.65; Percent Bias (PBIAS) < $\pm 15\%$), confirming its reliability. Results indicate that the REA-MME approach combining W_1 , W_2 and W_5 outperforms both SA and individual GCMs, reducing root mean square error (RMSE) by up to 25% and mean absolute error (MAE) by 10%. Among the models, CNRM-CM6-1 best captured Southwest Monsoon rainfall, while MPI-ESM1-2-LR performed better during the Northeast Monsoon. Future rainfall (2031–2050) is expected to increase by up to 18% in May–June and 38% in October–November under SSP2-4.5, with larger increases of 24% and 42% under SSP5-8.5. April rainfall, however, is expected to decline sharply by more than 41% in both scenarios. MME-REA consistently moderates projected changes compared to SA, particularly under SSP5-8.5. The corresponding streamflow projections reflect similar patterns, with increases of 24%–28% during the monsoon months and declines of 37%–41% in April. Compared to SA, MME-REA produces lower streamflow peaks (e.g., 28% vs 33% in October, 13% vs 18% in May) and less severe declines (37% vs 41% in April).

The findings highlight the importance of advanced ensemble techniques for improving the reliability of climate and hydrological projections. The refined REA method effectively captured seasonal variability, providing more accurate estimates essential for water management. These insights support targeted adaptation strategies to strengthen climate resilience in the Maha Oya Basin. Future studies should refine model selection, integrate land-use changes, and incorporate machine learning-based weighting to further reduce uncertainty.

Keywords: Climate change, CMIP6 GCMs, HEC-HMS, Precipitation projection, REA

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Enhancing Climate Impact Projections on River Flow Through Multi-Model Ensemble Techniques

