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Development of a Modified SCS Curve Number Method to Estimate Runoff in Small Catchments in Sri Lanka

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Abstract

The conventional SCS Curve Number (SCS-CN) method is the most widely used approach for runoff estimation in ungauged catchments, but its static, table-based parameterization poorly represents the dynamic runoff response of tropical catchments. This study develops a modified SCS-CN method for 10+ small catchments in the wet, intermediate, and dry zones of Sri Lanka by integrating causal discovery, structural equation modelling (SEM), physics-informed neural networks (PINNs), transfer learning, and uncertainty quantification within a single framework. Causal discovery first identifies the rainfall, soil, land-use, and catchment characteristics that drive runoff generation, and SEM quantifies their direct and combined effects, replacing the static tabulated curve number with a dynamic, catchment-specific CN function. This dynamic CN is then embedded as a physical constraint in a PINN trained on observed rainfall-runoff data, while transfer learning extends the calibrated framework to data-scarce catchments and uncertainty quantification provides prediction intervals for each runoff estimate. The framework is evaluated through split-sample testing and benchmarked against the standard SCS-CN method and conventional data-driven models using Nash-Sutcliffe efficiency (NSE), percent bias (PBIAS), and root-mean-square error (RMSE). By combining physically interpretable structure with data-driven adaptability, the modified method is designed to reduce the parameter uncertainty of the conventional approach and to provide reliability-quantified runoff estimates for water resources planning, flood design, and agricultural water management in ungauged tropical catchments.

Keywords: *causal discovery; physics-informed neural networks (PINN); rainfall-runoff modelling; SCS-CN method; transfer learning; tropical hydrology*