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Integrating Hydrological Modeling and Sustainability Indicators: A SWAT–WSI Framework for the Bundelkhand Region

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The Bundelkhand region in central India exhibits significant rainfall variability, frequent droughts, and escalating pressure on water resources, hence requiring dependable hydrological modelling and sustainability evaluation. This study utilised the Soil and Water Assessment Tool (SWAT) to simulate watershed-scale hydrological processes in the Bundelkhand region, with model calibration and validation performed utilising a cloud-based computing framework in Google Colab. The modelling methodology was established in a Python environment to facilitate quick data preprocessing, parameter sensitivity analysis, calibration, and validation. Calibration was conducted utilising observed daily streamflow data through the optimisation of sensitive hydrological parameters, then followed by validation over an independent period to assess model resilience. The evaluation of model performance was conducted utilising the Nash–Sutcliffe Efficiency (NSE), coefficient of determination (R^2), and percent bias (PBIAS). Alongside the study of hydrological performance, watershed conditions were assessed utilising the Watershed Sustainability Index (WSI), which integrates hydrological, environmental, and managerial factors to determine the overall sustainability state of the Bundelkhand watershed. The findings demonstrate that the calibrated SWAT model effectively replicates observed streamflow during both calibration and validation phases, but the WSI analysis underscores significant sustainability issues related to water supply and management in the region. The amalgamation of SWAT modelling and sustainability assessment inside a cloud-based platform offers a resilient and replicable framework for facilitating watershed management and water resource planning in drought-affected areas like Bundelkhand.