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Innovations in Hydrological Modeling: A Standalone Approach to GAML Equation Enhancement for Runoff and Sediment Yield Estimation Using WEPP model

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Accurate estimation of infiltration rates is crucial for hydrological modeling, impacting predictions of runoff, sediment transport, and related phenomena. Various infiltration models, categorized as empirical, semi-empirical, and physically based, have been developed to compute cumulative infiltration and infiltration rates for these purposes. Because of its simplicity and accuracy, the Green–Ampt (GA) infiltration equation has been widely used for simulating 1-D (vertical) infiltration into the soil. The modification of GA equation by Mein and Larson for steady rainfall conditions (GAML,1973., etc.,) is widely employed in different hydrological modeling software such as ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation), CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems), and WEPP (Water Erosion Prediction Project), suggests the versatility of the model approach. However, its assumption of a sharp wetting front and uniform soil moisture content tends to overestimate low-flow runoff events. The present study proposes a simple, standalone methodology to refine the GAML equation employed for infiltration calculations in the WEPP model. The advantage of the WEPP model is that it can simulate runoff and soil loss events on an hourly, daily, monthly, annual, and event scale; Spatial and temporal distribution of soil loss and deposition can be estimated, and hillslope to watershed scale studies can be performed. Refinement entails estimating hydraulic conductivity (K) and soil moisture () distribution in vertical and horizontal (2D) soil matrices before and after ponding scenarios as a linear equation of infiltration. A new algorithm was developed based on the refined GAML (R-GAML) parameters to estimate revised ponding time and infiltration rates based on experimental results, enhancing the accuracy of runoff predictions. Laboratory experiments on sand, clay, and sandy clay soils are utilized to estimate the soil infiltration parameters. The WEPP model was then employed to simulate runoff for a small agricultural watershed with the outlet at T. Narasipura station (of Cauvery River, India). The R-GAML and conventional GAML equations were used for runoff simulation and validated with the observed runoff data. The overestimation of low-flow runoff events using the conventional GAML was substantially reduced by the newly developed method, and the performance of R-GAML versus GAML was evaluated using correlation coefficient (0.937, 0.905), RMSE (16.471, 35.905), and NSE (0.968, 0.915) performance matrices for the Indian context. Furthermore, this research aims to extend i) runoff and sediment yield (SY) simulation using the R-GAML equation from the field scale to the river basin scale (upscaling), ii) study the impact of Land Use and Land Cover (LULC)

change on runoff and SY production by multi-site and multi-temporal calibration approach using the WEPP model. The findings offer valuable insights for urban planners in designing drainage networks, for agricultural water management in scheduling reservoir water release, and for deriving Best Management Practices (BMPs) in the Cauvery basin, which faces transboundary challenges due to rising water demand.