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Loss Modeling with a Data-Driven Approach in Event-Based Rainfall-Runoff Analysis

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Mathematical models require the estimation of rainfall abstractions for accurate predictions of runoff. Although loss models such as the constant loss and exponential loss models are commonly used, these methods are based on simplified assumptions of the physical process. A new approach based on the data driven paradigm to estimate rainfall abstractions is proposed in this paper. The proposed data driven model, based on the artificial neural network (ANN) does not make any assumptions on the loss behavior. The estimated discharge from a physically-based model, obtained from the kinematic wave (KW) model assuming zero losses, was used as the only input to the ANN. The output is the measured discharge. Thus, the ANN functions as a black-box loss model.

Two sets of data were analyzed for this study. The first dataset consists of rainfall and runoff data, measured from an artificial catchment (area = 25 m2) comprising two overland planes (slope = 11%), 25m long, transversely inclined towards a rectangular channel (slope = 2%) which conveyed the flow, recorded using calibrated weigh tanks, to the outlet. Two rain gauges, each placed 6.25 m from either ends of the channel, were used to record rainfall. Data for six storm events over the period between October 2002 and December 2002 were analyzed. The second dataset was obtained from the Upper Bukit Timah catchment (area = 6.4 km2) instrumented with two rain gauges and a flow measuring station. A total of six events recorded between November 1987 and July 1988 were selected for this study.

The runoff predicted by the ANN was compared with the measured runoff. In addition, results from KW models developed for both the catchments were used as a benchmark. The KW models were calibrated assuming the loss rate for an average event for each of the datasets. The results from both the ANN and KW models agreed well with the runoff measured from the artificial catchment. The KW model is expected to perform well since the catchment is completely impervious and the losses are small. Thus, the good agreement of results between the ANN with the KW model results demonstrates the applicability of the ANN model in modeling the loss rate. Comparing the modeled runoff with the measured runoff for the Upper Bukit Timah catchment, it was found that the KW model was not able to produce the runoff from the catchment accurately due to the improper prescription of the loss rate. This is because the loss rate varies over a wide range of values in a real catchment and using the loss rate for an average event did not provide truly representative values for the catchment. Although the same dataset was used in the training of the ANN model, the ANN model was able to produce hydrographs with significantly higher Nash-Sutcliffe coefficients compared to the KW model. This analysis demonstrates that the ANN model is better able to model the highly variable loss rate during storm events, especially if the data used for calibration is limited.

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