B205

Testing and Improving a Distributed Rainfall-Runoff Model Using Hillslope Surface Flow Observation

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This study evaluates a kinematic wave-based distributed hydrological model (1K-DHM) using both river discharge and hillslope surface flow duration observed by time-lapse cameras in a steep experimental catchment. While the original model reproduces hydrographs reasonably well, it overestimates surface flow duration due to structural limitations in representing vertical losses. By incorporating a Green-Ampt based vertical percolation scheme, the model improves the reproduction of both hydrograph shape and slope surface flow duration.

1. Introduction

Kinematic wave-based distributed models have effectively simulated slope lateral flows and reproduced flood hydrographs in mountainous catchments. However, these models typically lack explicit vertical infiltration schemes, and validation based solely on downstream hydrographs often fails to reveal structural limitations. This abstract presents Choi et al. (2026) that utilized time-lapse camera observations that directly captured hillslope surface flow from 2021 to 2023.

This study aims to test and improve the structure of a 1 km distributed hydrological model (1K-DHM) by comparing slope surface flow duration and downstream discharge responses in the Shigaraki Experimental Catchment, incorporating the Green-Ampt (GA) model as a vertical percolation scheme.

2. Study Area and Observation Data

This study focuses on the Shigaraki Experimental Catchment (24.6 ha) located in Shiga Prefecture, Japan (Figure 1). Since the catchment area is less than 1km², a 5 m resolution DEM was used to generate the model grid. Hillslope surface flow was monitored using time-lapse cameras capturing images every 10 minutes.

Due to space limitations, this paper focuses on a rainfall event from August 16 to 18, 2022, during which the highest precipitation was recorded. Rainfall was measured using two tipping-bucket gauges, one in an open area and another under the forest canopy. River discharge was monitored at a triangular weir located at the downstream outlet.

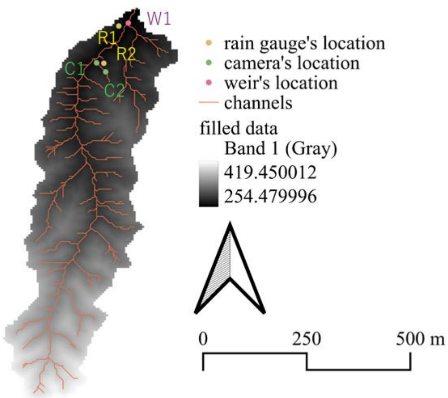

Fig. 1 Catchment map showing the 5-meter DEM, river channels, observation stations, and catchment boundary.

3. 1K-DHM Simulation for the 2022 Event

The model was applied to simulate the 2022 flood event using seven parameter sets (PS 1-7). Figure 2 compares the observed and simulated hydrographs and the duration of slope surface flow at the downstream site. All parameter sets achieved moderate to high Nash-Sutcliffe Efficiency (NSE) values (0.49-0.63). PSs 1, 3, and 4 reproduced peak discharge relatively well, with small peak discharge errors (PDE of -1.6%, -8.9%, and -5.6%), respectively, while PSs 2 and 7 provided the best overall hydrograph fit (NSE: 0.629 and 0.601; RMSE: 0.044 m^3s^{-1} for both).

However, peak discharge was overestimated in several cases, indicating sensitivity to parameter selection. To evaluate slope surface flow duration, the Jaccard Index was calculated based on the overlap period between observed and simulated surface flow. The indices for PS 2 and PS 7 were low (0.399 and 0.518), indicating overestimation of surface flow duration.

These results indicate that the best parameter did not capture slope surface flow. This limitation occurred because the original model uses only slope lateral flows, leading to unrealistically long surface flow duration.

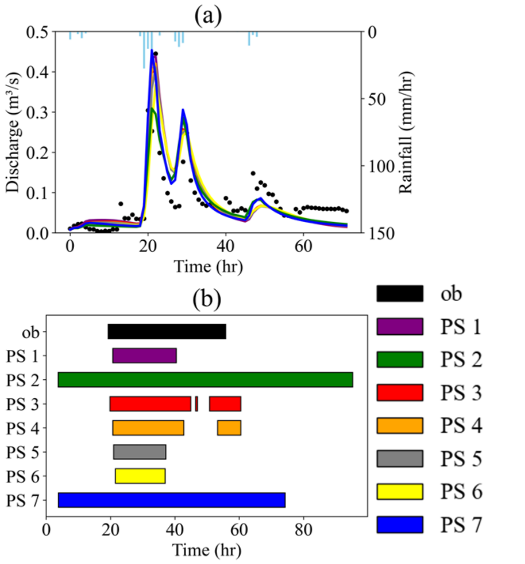

Fig. 2 Simulation results of PS 1-7, ob means observation data (dots in hydrographs): (a) hydrograph, (b) slope surface flow bar chart

4. Improvement by Green-Ampt

To better represent slope surface flow in the original model, we integrated the GA model into 1K-DHM as a vertical percolation loss scheme.

A new parameter set (PS 8) was defined by manual calibration based on PS 1. Simulation results using PS 8 are shown in Figure 3. PSs 2,3, and 5 were also utilized for comparison in Figure 3. Although peak discharge was slightly overestimated (PDE = 10.57%), the overall hydrograph shape was reasonable (NSE = 0.507, RMSE = 0.050 m^3s^{-1}). The Jaccard Index increased to 0.745, indicating improved reproduction of slope surface flow duration.

These results suggest that introducing vertical percolation losses reduces the unrealistic tendency toward saturation in the original model and mitigates the excessive slope surface flow duration.

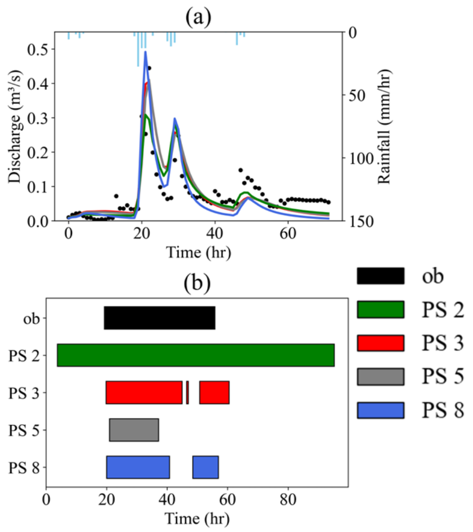

Fig. 3 Comparison of PS 2, 3, 5 and 8 at slope downstream ob means observation data (dots in hydrographs): (a) hydrograph, (b) slope surface flow bar chart

5.Conclusion

This study evaluated the 1K-DHM model using both river discharge and slope surface flow duration. While the original model reproduced discharge reasonably well, it overestimated surface flow persistence due to structural limitations. By introducing a GA-based vertical percolation scheme, the modified model improved agreement with observations, particularly in recession behavior and surface flow duration.

Reference

Choi, S., Tanaka, T., Tachikawa, Y., Yorozu, K: Testing and improving a distributed rainfall-runoff model using slope surface flow as a new observation metric, Hydrological Research Letters, 2026 (in print).

Tanaka, T., Tachikawa, Y.: Testing the applicability of a kinematic wave-based distributed hydrologic model in two climatically contrasting catchments, Hydrological Sciences Journal, 60(7-8), pp. 1361-1373, 2015