Lumping a Physically-based Distributed Sediment Runoff Model with Embedding River Channel Sediment Transport Mechanism

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Total runoff and sediment loads from hillslopes to and storage in river channel reaches can disrupt aquatic habitats, impact river hydromorphology, and water quality. It is often convenient to visualize a catchment as consisting of the channel network and the contributing areas that can be described as hillslopes. The reasonableness of this characterization varies, depending upon the hydrologic systems under consideration and upon the scale of consideration (small vs. large scale). In the fact, the source area of sediment for large catchment scale is primarily the river channel bed and banks, hillslope processes only feeding material for subsequent storage lower down the slope or in the river channel. To accommodate this, the recent developments of one-dimensional model from this study are physically-based distributed sediment runoff model and its lumping with embedding river channels sediment transport mechanism.

The advantage to lump a distributed model is to produce a new lumped sediment runoff model version as interest in sediment runoff modeling extends to large catchments scale, to derive lumped model parameters keeping the physical meanings of an original distributed model without any additional calibration, and to reduce computational time respectively. Those models can be used as a modeling tool for simulating the time-dependent response of runoff and sediment transport processes at the catchment scale which facilitates the analysis: (1) total runoff and sediment loads in both hillslopes and river channel processes; (2) interacting processes of erosion sources and deposition; and (3) internal catchment behaviors.

The proposed lumped model on hillslopes is divided into two parts: lumping of the kinematic wave distributed rainfall-runoff model and lumping of the distributed sediment transportation model that takes into account soil detachment by raindrop and hydraulic detachment or deposition driven by overland flow. A kinematic wave distributed rainfall-runoff model is lumped based on the assumption of steady state conditions. Soil detachment and deposition from an entire hillslopes are simulated by the balance between the current sediment storage and the maximum sediment storage, which is estimated from a distributed sediment runoff model as a function of total surface water storage of the lumped rainfall-runoff model.

The eroded soils from hillslopes defined as wash load provided to stream networks flow with sediment transport mechanism and routing process. The total sediment load within river channels consists of the sum of the bed-material load and wash load. Sediment transport mechanism of river channels incorporates sources of bed materials load for both suspended bed material load and bed load, which are composed of grains found in the stream bed.

The principal sediment transport mechanism controlling model behaviour in the simulations are the transport capacity of overland flow and the river channels flow generation specified in terms of stream power, storage, and release of the water and sediment concentration fractions.

The Lesti River basin, East Java, Indonesia is selected for the application of those models.