On reliability of a rainfall-sediment-runoff model

Graduate school of engineering, Kyoto University, Student Member, ○ Takahiro Sayama
DPRI, Kyoto University, Fellow, Kaoru Takara
DPRI, Kyoto University, Member, Yasuoto Tachikawa

1 Introduction Damage of water and sediment related disasters tends to be enormous particularly in developing countries. A hydrologic model may be used to analyze physical phenomenon of disasters. Complex physically-based rainfall-sediment runoff models have been applied with well calibrated parameter vectors, but it is now necessary to evaluate the simulation uncertainty with an assumption that the parameter vector cannot be optimized in ungauged basins.

The objectives of this research is to estimate rainfall-sediment-runoff simulation's uncertainty induced by parameterization errors and to evaluate the effective observation types and their accuracy. This research proposes a reliability evaluation method using the Monte Carlo simulation technique, and applies it to the Lesti River basin, Indonesia.

2 Rainfall-sediment runoff model

A spatially distributed rainfall-sediment-runoff model is constructed [1]. The model simulates sediment yield and deposit processes based on the transportation capacity of overland flow on each grid-cell with each time step. Yielded sediment on slope grid-cells moves in the flow direction derived from a DEM to river grid-cells, on which bed load and suspended load are calculated (Figure 1) .

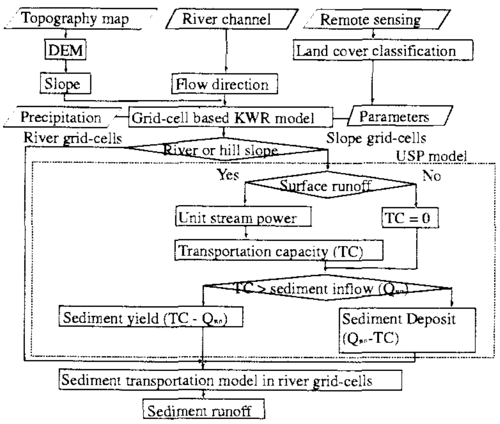

Figure 1 Flowchart of the rainfall-sediment-runoff model

3 Simulation at the Lesti River basin The model simulates sediment runoff and yield for a rainy season from November 1995 to April 1996 in the Lesti River basin (625 km^2).

Figure 2 shows the simulation results. Case 1 considers current land cover condition classified with ADEOS/AVNIR remote sensed image (June 4 in 1997). Simulated sediment runoff volume is 0.4 million m^3, which is adequate compared to sedimentation at a dam reservoir located to the downstream of the Lesti River. Case 2 represents the simulation results with an assumption that all forest area is cultivated by deforestation. Note that we assume that the forest area has 0.5 m of saturated and unsaturated subsurface layer, while the cultivated area does not have it. According to the simulation, deforestation increases the sediment yield from 0.3 million m^3 to 0.6 million m^3.

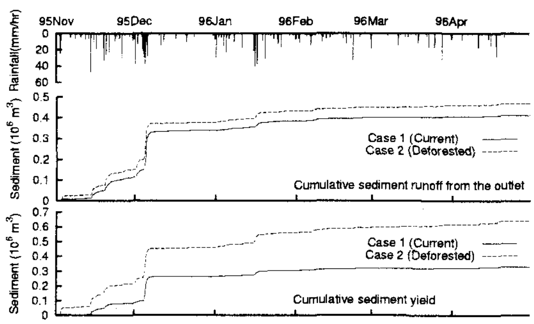

Figure 2 Simulated cumulative sediment runoff at the outlet and sediment yield from the basin

4 Reliability evaluation We evaluate the reliability of the simulation in the Lesti River basin. This research focuses on sediment runoff and sediment yield during three days (*SevereEvent*) from December 4 to December 6 in 1995, in which there was a severe storm (total rainfall : 389 mm). Deterministic simulation results of the sediment runoff and yield during *SevereEvent* were 0.22 million m^6 and 0.18 million m^3 respectively.

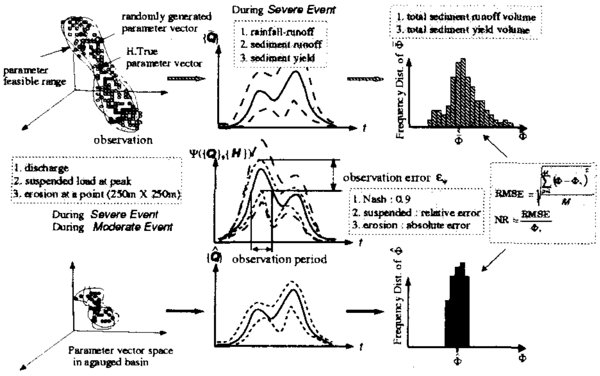

Figure 3 The effect of observation on sediment runoff simulation uncertainty

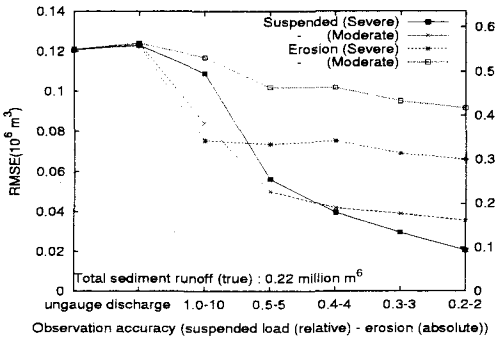

Figure 4 The effect of observation on sediment runoff simulation uncertainty

The schematic diagram of the reliability evaluation method is shown in Figure 3. The procedure is as following.

1. Using a parameter vector used for the deterministic simulation of Case 1 (H.True parameter vector), the model calculates output including state condition, which is assumed to be true values.
2. The model simulates rainfall-sediment-runoff by 500 times during *SevereEvent* with randomly generated parameter vectors that follow estimated stochastic parameter distributions. We obtain an error distribution compared with the true values and quantify the distribution with a root mean square error (RMSE) and a normalized RMSE (NR). The values may be representative errors without calibration (in an ungauged basin).
3. We suppose observed data regarding discharge, suspended load, and erosion are available during *SevereEvent* or *ModerateEvent* from November 19 to 21 in 1995 (total rainfall : 137 mm).
4. Considering maximum observation errors, observed data Ψ_{obs} may be within a range.
$$\Psi_* - \varepsilon_\Psi \leq \Psi_{obs} \leq \Psi_* + \varepsilon_\Psi \quad (1)$$
where Ψ_* is the hypothetical true value, ε_Ψ is a maximum observation error.
5. This approach assumes that all parameter vectors whose simulation results are in the observation range have potential to be accepted by a model user. We calculate the error distributions (RMSE and NR) when the accepted parameter vectors are used for the simulation. If these RMSE and NR are smaller than those of step 2, observed data seem to be effective to reduce the uncertainty.

5 Results and discussions

Figure 4 shows the RMSEs and NRs of sediment runoff depending on observation types (right corner) and observation errors. The horizontal axis represents the observation accuracy described with relative errors for suspended load observations and the absolute errors for erosion observations.

The results shows that the NR of sediment runoff simulation during *SevereEvent* is about 0.55 in an ungauged basin and it cannot be reduced with discharge data. Calibration with accurate suspended load data during *SevereEvent* can reduce the uncertainty. The suspended load data during *ModerateEvent* is also effective, but the NR cannot be reduced less than about 0.2. Erosion data during *ModerateEvent* may not be very useful in terms of the reduction the uncertainty of sediment runoff during *SevereEvent*.

The obtained information in the reliability analysis is just applicable in the Lesti River basin. However, the method can be applied in other basin with different conditions.

Reference

1) Sayama, T. and Takara, K., A distributed sheet erosion process model for sediment runoff prediction, *Journal of Hydraulic, Coastal and Environmental Engineering*, No **726** / II-62, pp. 1-9, 2003 (in Japanese).