Rainfall-runoff-inundation model application for volcanic debris flow assessment in Mount Merapi

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Volcanic debris flow or lahar is a hydrometeorological disaster happened in the rainy season in Mount Merapi. Following the 2010 eruptions more than 50 lahar events happened and caused material loss and casualties. Although the frequencies are decreasing, but in 2016 the disaster still happened as the unstable material from the volcano eruption remains at elevation higher than 1200 m above mean sea level (amsl).

Lahar is a Javanese term used to describe a rapidly flowing, high concentration, poorly sorted sediment-laden mixture of rock debris and water from a volcano that goes along river stream. It is a continuum flow type which covers debris flows, hyperconcentrated, streamflow, and mudflows. It comes as series of surges with maximum frontal velocity ranges from 5 m/s to 15 m/s. At Merapi lahar is likely to trigger by rainfall intensity of 40 mm in 2 h. Two types of triggering rainfall are: local stationary or orographic confined to slopes above 1200 m amsl and regional, migratory rainfall that moves from the northwest or the southwest. The latest mention usually leads to large-scale debris flow (>80,000 m^3 of deposits) (Lavigne et al. 2007).

Hydrological model such as rainfall-runoff-inundation (RRI) could be a useful tool for analyzing hydrometeorological disaster. The model uses full dynamic equations that based on diffusion wave assumption which are effective for flood assessment in both mountainous slopes and lowland plains. However, the application on flash-flood and debris flow is difficult because of the short duration and small area. The RRI model relies on satellite-rainfall and rain gauge data, while lahar occurs in a small-scale that constrained the use of coarse resolution of satellite-rainfall or poor resolution rain gauge network.

Previous studies confirmed that rain gauge-rainfall caused uncertainties and underestimated rainfall threshold for debris flow occurrence (Nikolopaulus et al., 2014; Staley et al., 2013; Marra et al., 2014). On the other hand, remote monitoring by weather radar such as an X-band multi parameter (X-MP) radar gives higher spatial and temporal resolution, which is desirable by lahar studies. It offers advantage to monitor rainfall in the initiation area and it could measure debris flow during short duration of storm event (David-Novak et al., 2004; Chiang and Chang, 2009).

In this paper, we improved the RRI model by applying X-MP radar information. A new submodule of debris flow assessment has also been introduced based on Takahashi theory (Takahashi, 2009). The theory considers debris flow initiation criteria depends on average slope, particle size and discharge per unit width. We used the improved model to analyze hydrologic condition in Gendol Catchment for 2 weeks observation in May 2016.

The radar-rainfall based model gave comparable results with the rain gauge-rainfall based model and the observed water depth information in the downstream area. The discharge information calculated by RRI model were not only useful for direct lahar assessment but could be important boundary information for other numerical model in ungauged sub-basin. Although direct verification in the ungauged upstream area is difficult, but in the future applying the model for real lahar event could be useful to test the improved RRI model performance in small-scale catchment.

Keywords: Rainfall-runoff-inundation model, X-MP radar, volcanic debris flow, rainfall, merapi