Ensemble rainfall forecast for lahar mitigation at Mount Merapi

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Debris flow in the slope of the volcano is sometimes called “lahar”, which is a wet mass of volcanic fragments flowing rapidly downhill. At Mt. Merapi of Indonesia, lahar occurs mostly as secondary disasters that happen almost every year during the rainy season. However, the study of lahar has two main problems. The first problem is lahar usually generates in a relatively inaccessible and dangerous area at an elevation higher than 1200 m above mean sea level (amsl). This problem causes difficulties in direct lahar monitoring. The second problem is the uncertainty of rainfall data at Mt. Merapi. This problem is caused by the unavailability of upstream rainfall information, great spatial distribution of rainfall, and the potency of destructive eruption impacts from an active volcano.

This study is conducted to solve those problems by developing a lahar mitigation method by the utilization of X-band multi-parameter (X-MP) weather radar and a numerical hydraulic model in Gendol River at Mount Merapi. The application of X-MP radar is able to give a more reliable and wider coverage area of real-time rainfall and lahar potency information at Mt. Merapi. The utilization of radar is done through (1) Developing short-term ensemble rainfall forecast to know the future rainfall information, (2) Applying the short-term ensemble rainfall forecast to existing critical line of lahar to know the potency of lahar occurrence, and (3) Applying the short-term rainfall forecast into a modified distributed hydrological model to know lahar magnitude and the inundation potency.

An ensemble rainfall forecasting by advection model is done to a rainfall case on 17 February 2016. The predicted rainfall values still have poor spatial distribution, but in general, the average areal rainfall was in agreement with real observed data. A further application to the snake line analysis could determine the potency of lahar occurrence based on the method proposed by Ministry of Land, Infrastructure, and Transportation of Japan (MLIT). The plotting gives the result that the predicted rainfall based snake line exceeds the critical line and hence, indicates the potency of future rainfall to trigger the lahar in Gendol River.

Applying the mean ensemble forecast rainfall to a hydrological model of Rainfall-runoff and inundation (RRI) model, earlier lahar information could be obtained. The RRI model was modified by giving more resistant to the flow in the discharge formula by adjusting the Manning roughness coefficient and integrating some empirical equations of lahar properties i.e. travel distance, volume, and mean flow velocity. This study becomes the first study to couple the rainfall information from X-MP radar and a distributed hydrological model for direct lahar simulation. The Manning coefficient roughness adjustment is applied to each of the stream mesh in the terrain data. It causes the flow to have higher shear stress in the flatter elevation, hence, acts as stoppage mechanism. The mean-ensemble rainfall-based model gave the same simulation results with the observed X-MP radar data-based model. The validation of the water depth from the simulation of X-MP radar-based models and means ensemble based model were also in agreement with the measured water depth. On the other hand, the rain gauged-based model gave overestimation results. The calibration in the Putih catchment also showed the superiority of X-MP radar

comparing to the ground-based measurement.

Overall the present framework offers suggestions for better treating the uncertainty of lahar disaster according to the hydro-meteorological condition and thus, can serve as a reliable and effective system for a better remote lahar mitigation.

Keywords: Rainfall forecast, Hydrological model, X-MP radar, lahar, Disaster mitigation

