Influence of antecedent rainfall on rainfall thresholds for triggering shallow landslides in Korea

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1. INTRODUCTION

Rainfall is widely recognized as one of the major landslide-triggering factor. Since the Korean Peninsula belongs to the East Asian monsoon region, more than 60% of the annual precipitation is in a form of heavy rainfall influenced by typhoon and rainy spell from June to September, and consequently landslides are occurring intensively during this period. Therefore, numerous studies have been focusing on rainfalls in order to interpret the relation with landslide and, based on this, endeavored to construct early warning and evacuation system and its enhancements, considering rainfall factor as the top priority. However, the relationship between rainfall and triggering of landslide is poorly understood. In this study, we analyzed the rainfall threshold for the triggering of shallow landslides and the influence of antecedent rainfall on their relationship in Korea, based on hourly rainfall data for 478 shallow landslides during the past five decades.

2. METHODS

In this study, we analyzed 478 landslides that could be identified with their occurrence locations and times as well as rainfall data owing to the reports of local governments and daily newspapers among the landslides caused by heavy rainfall throughout Korea during 1963–2012.

This study used the hourly rainfall data of the total 163 observatories including hourly data of meteorological observatories maintained by the Korea Meteorological Administration, disaster prevention weather data from automatic weather stations and real-time observational data of the rainfall stations of the Ministry of Land, Infrastructure and Transport and the Korea Water Resource Corporation provided by Water Management Information System. Rainfall data were collected from the nearest meteorological observatories from the locations of landslides, and the average distance between the locations of landslides and meteorological observatories and its standard deviation were 4.6±2.9 km.

For rainfall analysis, if a rainfall continued from the beginning of the rainfall influenced by typhoon or heavy rainfall until the occurrence of a landslide, it was defined as a landslide-triggering rainfall and a single rainfall event, and event cumulative rainfall (*ECR*), rainfall duration (*D*) and mean rainfall intensity (*I*) were calculated. In this study, single rainfall events were classified by the non-rainfall duration more than 24 hours before the beginning of a rainfall according to the methodology suggested by several previous studies (Fig. 1). The *I-D* threshold for the triggering of shallow landslide was determined by quantile regression analysis using statistical software "*R*" package, and in order to understand the influence of antecedent rainfall upon this, absolute antecedent rainfall (*AAR*) and calibrated antecedent rainfall (*CAR*) for 3, 7, 10 and 20 days were calculated.

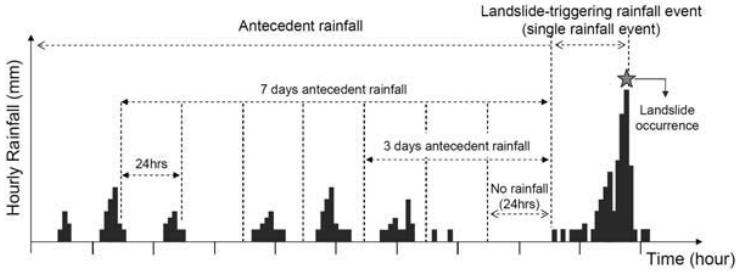

Fig. 1. Definition of rainfall event in this study.

3. RESULTS

3.1. *I-D* threshold

Fig. 2 shows *I-D* plots in double-logarithmic coordinates and quantile regression lines for the triggering of

shallow landslides in Korea. *I-D* threshold was determined by regression lines of the 2nd percentile. The threshold line is expressed as

$I = 9.64D^{-0.27}$ ($4 \leq D \leq 76$ hrs)

where I and D are expressed in millimeters per hour and hours, respectively. This threshold indicates that for rainfall event having duration of 4 hours and 76 hours, rainfall intensity of 6.6 mm/hr and 3.0 mm/hr, respectively, has potential to cause landslides.

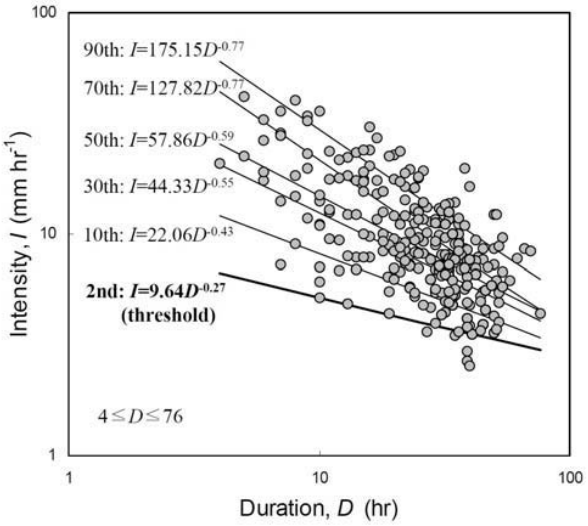

Fig. 2. *I-D* plots and quantile regression lines for the triggering of shallow landslides in Korea.

3.2. Influence of antecedent rainfall on *I-D* threshold

For the relationship between the event cumulative rainfall of landslide-triggering rainstorm and the absolute antecedent rainfall, the ratios of the spots existing at the upper side of 1:1 diagonal line were 99.2%, 94.6%, 90.8% and 46.2% respectively for antecedent rainfall of 3, 7, 10 and 20 days. As the analyzed antecedent rainfall duration increased, the influence of event rainfalls gradually decreased, but in the comparison with antecedent rainfall up to 10 days, the influence of event cumulated rainfall was much more remarkable. In all cases of 3, 7, 10 and 20 days, if the absolute antecedent rainfall was more than the event cumulative rainfall for the triggering of shallow landslides (i.e., $AAR \geq ECR$), it obviously showed that landslides occurred by rainfall with shorter duration and lower intensity. Particularly, in the relation with antecedent rainfalls of 7, 10 and 20 days for which a quantile regression analysis was possible, there existed distinct difference in *I-D* threshold. In case of landslides with heavy antecedent rainfall (i.e., $AAR \geq ECR$), the exponent β was in a range of 0.27–0.35, which was slowly decreasing according to the increase of rainfall duration in comparison with the exponent β in a range of 0.71–0.74 for the landslides with high event cumulative rainfall (i.e., $AAR < ECR$).

For the relation between the event cumulative rainfall of landslide-triggering rainstorm and the calibrated antecedent rainfall, the ratio of the spots existing at the upper side of 1:1 diagonal line was more than 95% so that even if the analyzed antecedent rainfall duration increased, the impact of event cumulative rainfall was shown to be remarkable. In addition, as same as the case in the relation with absolute antecedent rainfall, for all cases of 3, 7, 10 and 20 days, landslides occurred by rainfall with shorter duration and lower intensity, in case the calibrated antecedent rainfall was more than the event cumulative rainfall of landslide-triggering rainstorm (i.e., $CAR \geq ECR$). Particularly, in the relation with 20 days calibrated antecedent rainfall, it showed a distinct difference in *I-D* threshold.

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