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A method for predicting debris-flow occurrence based on a rainfall and sediment runoff model

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Abstract

Based on a basin scale rainfall runoff model, we proposed a prediction method of debris-flow occurrence on steep mountain slopes related to hydrological processes such as the rainfall infiltration, the surface flow and the slope stability. For example, in one case that the soil layer is unsaturated and a landslide does not occur in the slope even though the groundwater level rises in the slope soil layer during a rainfall event, it is unlikely for a debris flow to occur on the slope. However, if the soil layer is more unstable due to fully saturation and a surface flow also takes place on the slope, the possibility of debris-flow occurrence gets much higher. According to such a consideration, the slope conditions on hydrological processes during heavy rainfalls were classified into six patterns. For these patterns, the possibility of debris-flow occurrence was investigated qualitatively. Then, SiMHiS (Storm Induced Multi-Hazards Information Simulator) by Yamanoi and Fujita was employed as a rainfall runoff model. A slope stability model has been already installed in SiMHiS. Therefore, this model can simulate the time variations of the safety factors for landslides as well as the saturation degrees and the hydrographs of the surface flow for the slopes. SiMHiS was applied to the sediment disasters due to a heavy rainfall in July 2017 in the Akatani river basin to examine the occurrence patterns of debris flow. Also, the differences in the occurrence patterns were shown for other two rainfall events. Using the simulation result on the safety factor, the saturation degree and the surface flow discharge, it was noted whether debris flows took place or not, and the debris-flow occurrence patterns on the slopes in the basin could be identified.

Keywords: debris flow; rainfall runoff model; baisn scale; occurrence process of debris flow; sediment disaster

1. Introduction

An empirical approach to predicting debris-flow occurrence is a standard method for practical applications. A warning system based on a critical rainfall is used worldwide for road risk management for sediment disasters and a warning alert for the debris-flow occurrence is issued using a rainfall monitoring system. There are also theoretical approaches, but the theoretical research has so far focused on the mechanisms of debris flows and has not discussed the debris-flow process as one of the components in a rainfall runoff system. Therefore, the critical rainfall for debris-flow occurrence cannot be found from a previous theoretical research. Because debris flows as well as floods in a basin are typical phenomena in the hydrological process in the basin, they should be analyzed with a basin scale rainfall runoff model

Previous studies on debris flows have shown that there are several processes of debris-flow occurrence. The sediment deposits in a steep channel with a gradient of more than 15 degrees could be an original source of debris flows. In a steep mountain slope, sediment movement such as landslides and slope erosion could initiate debris flows. The debris flow occurs related to the variables in the hydrological process on the slope such as the slope stability, the saturation degree and the surface flow. The processes of debris-flow occurrence are thought to be different depending

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Rain B has a same rainfall duration with Rain A, but the intensity is half of Rain A. Fig.5(b) show the distribution of debris-flow occurrence patterns for Rain B. A few landslides occur because lower rainfall intensity reduces the landslide occurrence. Rain C has a smaller cumulative precipitation than Rain A, but the rainfall intensity is same as Rain A. Therefore, many landslides occur as shown in Fig.5(c). However, the debris-flow occurrence patterns are dominantly *Pattern 3*and *Pattern 4 (b)*. Particularly, half of the landslides has *Pattern 3*. The slope soil layer become unstable and accelerated, but it can be saturated with water because of lower cumulative precipitation.

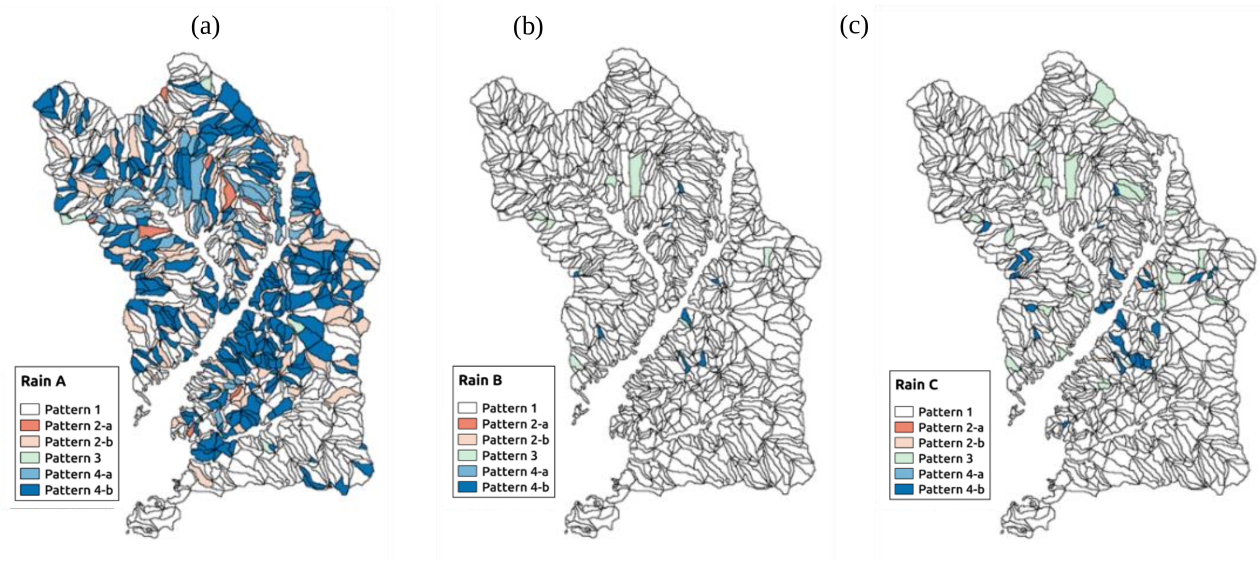

Fig.5. (a)-(c) Distributions of debris-flow occurrence patterns for Rain A, B and C

5. Conclusion

Debris flows occur from hydrological processes on mountain slopes such as rainfall infiltration and surface flow on the slopes. The slope stability is also related to the initiation of debris flow. Therefore, the time variations of the saturation degree and the safety factor of slope soil layer, as well as the hydrograph of surface flow on the slopes, are very important indices. In this study, the difference of the features of the variations was investigated, and the patterns of the variations were clarified. Considering the relation between the patterns and debris-flow occurrence, the possibilities of debris-flow occurrence were qualitatively evaluated. A rainfall runoff model was applied to an actual river basin that experienced severe sediment disasters to verify effectiveness of this idea. The changes of the safety factor and the saturation degree and the hydrograph of surface flow were simulated to identify the patterns. Because the actual rainfall was very heavy, it was evaluated that most of the landslides transited into debris flows. This result agreed with the actual situation. It was evaluated that half of the landslides did not transit into debris flows if the duration of the rainfall was reduced to half of the actual rainfall with the same rainfall intensity. Using this method, it may be possible to identify the processes of debris-flow occurrence after landslides. However, in order to confirm the effectiveness of this method, it is necessary to apply this method to other sediment disasters.

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