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Estimating the effects of different heavy rainfall conditions on shallow landslide potential using a distributed landslide conceptual model

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In hilly countries such as Japan, quantifying landslide hazards and other risks associated with heavy rainfall is increasingly important. Quantification of critical rainfall conditions is fundamental to establishing warning and evacuation systems. Previous studies on rainfall conditions have focused on the relationship between shallow landslides triggered by heavy rainfall and the critical rainfall threshold, using probability analysis, rainfall duration-intensity analysis, and soil water indices. Although such studies of rainfall thresholds are useful, they do not necessarily identify the critical line (or limiting curve) among heavy-rainfall events. Advances in geographical information systems over the last decade mean that quantifying regional relationships between slope stability and landslide risk is now possible.

This study uses a distributed landslide conceptual model to show the effects of variable, heavy rainfall conditions on the potential for shallow landslides. The model uses a digital terrain model with 50 m cell dimensions to calculate the regional potential for shallow landslides, based on the distribution of shallow infiltration water, using Darcy's law and a safety factor estimated by infinite slope stability analysis for each cell. The model is applied to the upper Miyagawa River basin at Odai-cho (formerly Miyagawa village) in Mie prefecture. This area is especially suitable for estimating the effects of variable, heavy rainfall conditions on shallow landslide potential for two reasons. Rainfall in this area is among the highest in Japan, with mean annual rainfall from 1979 to 2007 of about 3200 mm/year, and maximum annual rainfall of 5200 mm/year in 2004. In 2004, typhoon no. 200421 caused severe sediment disasters in areas adjacent to the study area, but other heavy rainfall events in the same year did not cause severe sediment disasters.

Response analysis of data collected hourly during heavy rainfall events reveals that the potential for shallow landslides decreases dramatically when the parameter that designates effective soil cohesion is between 3 and 9 kPa. This finding indicates that temporal changes in shallow landslide potential are influenced by both temporal rainfall patterns and effective soil cohesion. The present study demonstrates that variable heavy rainfall conditions result in spatial and temporal fluctuations in the potential for shallow landslides, and that the potential for shallow landslides is determined by the interaction between rainfall characteristics and soil strength.