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Assessment of the probability of failure in rainfall-induced shallow landslide using physically based model and fuzzy point estimate method

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Traditional slope stability analysis mostly adopts the limit equilibrium method, which predetermines the slope failure surface, and assumes that failure occurs simultaneously at all points of the failure surface. The method is based on the balance of forces and torques. The slope stability is represented by the factor of safety. The lowest factor of safety obtained after repeated analysis indicates the most failure-prone slope surface. However, the factor of safety for only one slope failure surface is obtained when applying this method. The distribution and changes of factor of safety in the interior of the slope are not identified. In addition, the analysis of factor of safety is influenced by the uncertainty in soil mechanical parameters, whereas uncertainty is not quantified in the traditional deterministic analysis. Therefore, a probabilistic approach, which uses the probability distribution function to explain the randomness of parameters, is proposed for quantifying the uncertainty. Nonetheless, when the observation data are not sufficient for determining the probability distribution function, the fuzzy theory can be an alternative method for the analysis. The fuzzy theory is based on fuzzy sets. It expresses the ambiguity of incomplete sets of information using a membership function. Moreover, a correct judgment can be made without verbose iterations. Hence, the aim of this study is to examine the uncertainty in soil mechanical parameters. The membership functions between soil mechanical parameters, i.e. cohesion and angle of internal friction, were constructed based on the fuzzy theory. The fuzzy point estimation was used in combination with the hydrologic and mechanical coupling model on HYDRUS 2D and the Slope Cube Module. The local factor of safety at different depths of the slope was determined using the local factor of safety theory. The probability of failure at different depths was calculated through reliability analysis, which could serve as an early warning for subsequent slope failures.