Considering the Quantitative Effect of Antecedent Rainfall on Slope Stability to Predicting Rainfall-induced Shallow Landslides at the Basin Scale

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INTRODUCTION

In mountainous areas, landslides are a common geological phenomenon and often result in major financial losses, and even to major human life losses. Landslides are triggered by many external environmental factors among which rainfall is the most significant one. In previous studies of landslide-rainfall relationship, many researches focused on the intensities and durations of rainfalls and got the proper understanding. There only few studies considered the antecedent rainfall. For existing researching files about the effect of antecedent rainfall on rainfall-induced landslide are based on the empirical approach. This method have the advantage of simplicity using, but it considered the physics feature of hillside slopes as a 'black box' and overlooks the actually physical processes of landslide triggered by rainfall. So, In this paper, according to the physical mechanics of rainfall-induced shallow landslide, a physically based model considered the antecedent rainfall is presented, and using to predicting rainfall-induced shallow landslides at the basin scale.

HILLSLOPE HYDROLOGY MODEL AND SLOPE STABILITY MODEL

The hillslope hydrology model is consists of two mathematical parts (equations), one is used to describe the rainfall induced the ground water raising, and the other is used to describe the ground water recession after the rainfall stop. In this study, the expressions for ground water raising presented by Rosso et al (2006) is used. And the expressions for ground water recession is derived in this study.

$$h = \frac{apz}{Tb\sin\theta}[1-\exp(-\frac{1+e}{e-es_r}\frac{Tb\sin\theta}{az}t)] + h_0\exp(-\frac{1+e}{e-es_r}\frac{Tb\sin\theta}{az}t), \qquad for\ \frac{ap}{Tb\sin\theta} > 1 \quad (1)$$

$$h = h_a\exp(-\frac{1+e}{e-es_r}\frac{Tb\sin\theta}{az}t) \quad (2)$$

Where, p is the net rainfall, a is the upslope contributing area, b is the width of the topographic elements, h is the height of the ground water table, θ is the slope angle to the horizontal, s_r is the average degree of saturation, e is the average void ratio above the groundwater table, K is the saturated conductivity of the soil, t is the rainfall duration time, T is the hydraulic transmissivity, with $T = Kz$, z is the thickness of the landslide, h_0 is the initial height of ground water table before it rains; h_a is the height of groundwater table at the time of the antecedent rainfall stop, and the other parameters are as before. Here, h_a can be obtained by using expression (1) for set h_0=0. It should be note that before the antecedent rainfall happen, we can considering the simple case of no groundwater in a hillslope.

Here, Equation (1) is used to describe the rainfall induce the ground water raising, and the Equation (2) is used to describe the ground water recession after the rainfall stop. Equation (1) and (2) composed the hillslope hydrology model. By the hillslope hydrology model presented in this study, the quantitative effect of antecedent rainfall on groundwater table can be taken into account.

The slope stability model is derived in this study, based on the infinite slope assumption. The expression for the safety factor of a slope can be obtained as the following.

$$F_s = \frac{c + [(z-h)\gamma + h\gamma']\cos^2\theta \tan\varphi}{[(z-h)\gamma + h\gamma_{sat}]\sin\theta\cos\theta} \qquad (3)$$

where, c is the cohesion of the soil, σ is the normal total stress, u is the pore water pressure, and φ is the internal friction angle of the soil; γ is the average unit weight of the soil, γ_{sat} is the saturated unit weight of the soil, and γ' is submerged unit weight of the soil, z is the depth of the shallow landslide.

APPLICATION AND DISCUSSION

Baisha river basin of Dujiangya city is chosen as the study area to mapping prone areas of rainfall-induced shallow landslides from the application of the model presented in this study. In this study, the precipitation is assumed 100mm/d in Baisha river basin and antecedent rainfall is assumed to happen before 4 day and lasted 3 days with the precipitation of 100mm/d too. Based on the geological data of Dujiangyan, the Lithological formations in Baisha river basin had been divide as three major groups. The soil parameters for each groups were obtained by soil sample tests and consulting geological survey data and a handbook of engineering geology.

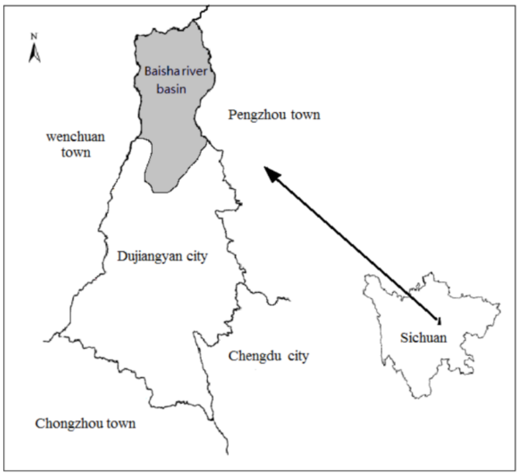

Fig. 1 Location of the Baisha River basin

CONCLUSIONS

(1)The quantitative effect of antecedent rainfall on groundwater table can be take into account by an additional initial height of groundwater table. By comparisons, the height of groundwater table of unconsidered the antecedent rainfall is lower than results of considered. (2) For a same slope, the results of the stability analysis may be different for considered or unconsidered the antecedent rainfall. That is to say, the antecedent rainfall effect on the shallow landslide should not be ignored. (3) Application is made in Baisha river basin. The results showed that antecedent rainfall has an obvious effect on shallow landslides. The percentage of unstable topographic cells obtained by considered the antecedent rainfall is larger than that unconsidered. Antecedent rainfall has strongly effect on rainfall-induced shallow landslide predicting. (4) The study show that considered the antecedent rainfall in mapping the hydrologic controlled shallow landslide prone area predicting and landslide hazard assessment are quite important. It is hope to improve the accuracy of results of rainfall-induced landslide hazard assessment and found useful forregional landslide forecast.

REFERENCES

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