THE ROLE OF FIELD SURVEY AND OPTIMAL PROCEDURE FOR CALCULATION ON SHALLOW LANDSLIDE PREDICTIONN

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INTRODUCTION

Predicting where landslides are likely to occur is key to preventing debris flow disasters. Since the pioneering work of Okimura, several physically based models predicting shallow landslide susceptibility have been developed, and such models are potentially a powerful way to evaluate the spatial pattern of shallow landslide susceptibility (e.g., Okimura et al., 1985; Wu & Sidle, 1995). Further, Okimura et al. (1985) indicated that the simple model combines an infinite slope stability analysis with a steady-state shallow subsurface flow was used as a reasonable approximation of a shallow landslide occurrence.

In most simulations for predicting landslide locations, many parameter values have been determined by back-calculations or by calibration against past observed events, which often were represented by mean values of a limited number of observed data. Here, we examine the role of field survey and optimal procedure for calculation on shallow landslide prediction using a detailed field survey data and a simple numerical simulation model.

THEORY

We calculated the critical steady-state rainfall required to cause shallow landsliding following the methods of Okimura et al. (1985) and Montgomery and Dietrich (1994). Thus, if saturated depth is less than soil depth, an infinite slope stability analysis can be used to compute the factor of safety (FS) as follows:

$$FS = \frac{c + (\gamma h \cos^2 I - h_s \gamma_w \cos^2 I)\tan\phi}{\gamma h \cos I \cdot \sin I} \qquad (1)$$

where c is effective cohesion, ϕ is the friction angle of the soil mantle, I is the angle of the bedrock surface, γ and γ_w are the specific weights of soil mantle and water, respectively, and h and hs are the soil and saturated water depths, respectively. We assumed that γ can be described by the equation

$$\gamma = \frac{\gamma_s h_s + (h - h_s)\gamma_t}{h} \qquad (2)$$

where γ_s and γ_t are the specific weights of saturated and unsaturated soil, respectively.

According to Darcy's law, the saturated water depth, hs, at a given steady-state rainfall intensity, r, can be described as

$$h_s = \frac{rA}{K_s \sin I \cos I} \qquad (3)$$

where A is the contributing area of the unit contour length, and Ks is the saturated hydraulic conductivity of the soil mantle. Therefore, if, then the critical steady-state rainfall required to cause shallow landsliding, *rc*, can be determined with equations 1 through 3 by setting FS = 1, as follows:

$$r_c = \frac{K_s \tan I \cos I \{c - \gamma_t h \cos I(\sin I - \cos I \tan\phi)\}}{A\{\gamma_w \cos I \tan\phi + (\gamma_s - \gamma_t)(\sin I - \cos I \tan\phi)\}} \qquad (4)$$

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STUDY SITE

We conducted a detailed field investigation at two hillslope sites in the western Hiroshima Mountains, and five hillslopes in the Saru River basin. The western Hiroshima Mountains are underlain by granite, while Saru River are underlain by sedimentary rocks. Recently, the heaviest rainfall triggered many shallow landslides in these areas.

FIELD SURVEY

We measured the surface topography using LiDAR (light detection and ranging) data and developed a 1-m DEM. We also mapped the edges of the recent shallow landslides (Fig. 1). Soil depth was measured with a cone penetrometer (knocking pole test). Knocking pole tests were conducted at intervals of 10–15 m. We conducted the tests at more than 100 points for each hillslope. Further, we estimated soil depth before the shallow landslide occurrence in landslide scars using data of LiDAR and knocking pole test

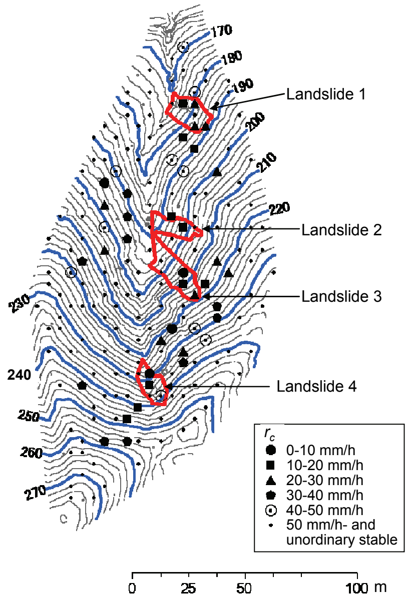

Fig. 1 Simulated results of the hillslope in western Hiroshima Mountains

RESULTS AND CONCLUSIONS

We showed a simulated result for one hillslope in western Hiroshima Mountains in Fig. 1. For this simulatin, we used observed spatial pattern of soil depth and 5-m grid cells. This result showed that in at least one mesh in each landslide scar, r_c was smaller than the observed maximum 1-hour rainfall (63 mm/h) (Fig. 1). Further, predicted r_c values were generally large outside the landslide area. This means that the predicted r_c well described landslide locations and the rainfall amount required to cause shallow landsliding.

When the grid cell size was set to 10-m to 25-m, the difference of predicted r_c between landslide scars and outside of landslide scars became small. Further, when we used averaged soil depth, instead of the observed soil depth at each measurement point, the predicted r_c could not describe spatial pattern of shallow landslide.

Here we showed that the choice of an optimal grid cell size and a detailed field survey of soil depth remarkably improves the precision of landslide susceptibility assessment. This finding indicate that if an optimal procedure for topographic index calculation are chosen and a detailed field survey is conducted, the existing simple models can yield results useful for landslide susceptibility assessment.

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