A Simple Method for Producing Probabilistic Shallow Landslide Hazard Maps

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Background and Objectives

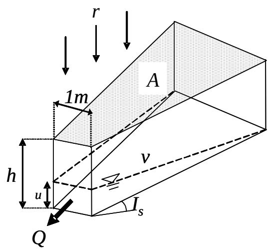
Predicting where and in what rainfall conditions are likely to trigger landslides is a key element in prevention of natural disasters. Recently, several physically-based models of predicting the landslide susceptibility have been proposed and showed that physically-based model have a powerful potential as a way to evaluate the probability of shallow landslide. However, several practical challenges, such as the problem of computation time and the ability to obtain adequate underground information, including soil thickness and soil hydraulic parameters, have to be overcome. To overcome these problems, we showed new data and proposed new method.

H-SLIDER method

Hillslope scale shallow landslide-induced debris flow risk evaluation method

Based on concepts of Okimura's model, SHALSTAB and SINMAP, we calculated Critical steady-state rainfall required to cause.

We tested this concept using detailed field observed data.



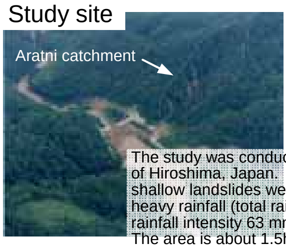
- Field measurements
  - Soil thickness (Knocking pole test)
  - Soil strength
  - Effective saturated hydraulic conductivity (Hydrological observation)
- DEM (D-Infinity Flow Direction Method)
  - Slope gradient
  - Drainage area

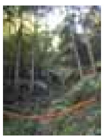
→ Critical steady-state rainfall required to cause slope instability (r_c)

$$r_c = \frac{K_s \tan I \left\{ \frac{c}{\cos I} - \gamma_t h (\sin I - \cos I \tan \phi) \right\}}{A \left\{ \gamma_w \cos I \tan \phi + \frac{(\gamma_s - \gamma_t)(\sin I - \cos I \tan \phi)}{\cos^2 I} \right\}}$$

Test of H-SLIDER Method

Study site





The study was conducted in Aratni catchment of Hiroshima, Japan. In June of 1999, four shallow landslides were triggered due to heavy rainfall (total rainfall 417mm, max. rainfall intensity 63 mm/h) in this catchment.. The area is about 1.5ha and underlain by granite.

K_s estimation

We measured hillslope runoff and soil pore pressure distribution in hillslope. We back-calculated lateral saturated conductivity using hydrometric data. Estimated value (0.05 mm/h) was larger than soil saturated hydraulic conductivity measured by small samples (less than 0.001 mm/h).
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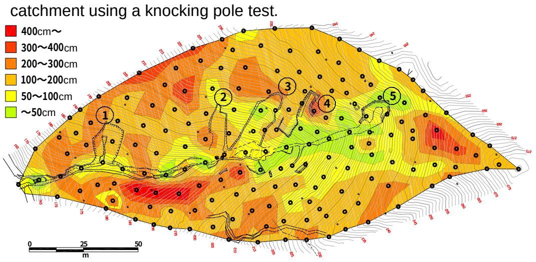
Soil thickness survey

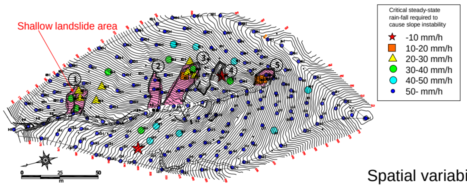
To clarify spatial patterns of soil thickness, we measured soil thicknesses at about 150 points in the catchment using a knocking pole test.



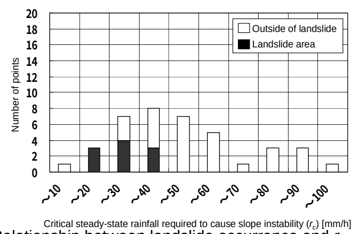
Knocking pole test

Applicability of H-SLIDER

The value of r_c in landslide scars were mostly smaller than observed maximum rainfall intensity in June 1999 (63 mm/h). This means that H-SLIDER method successfully identified shallow landslide location.



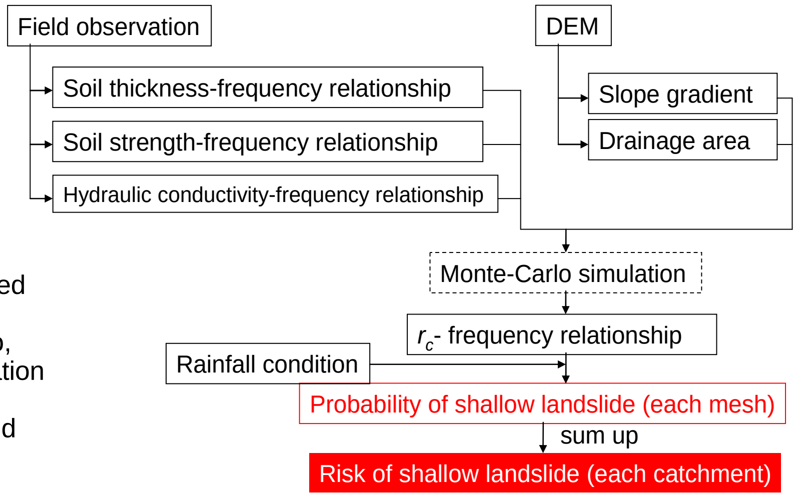
Spatial variability of r_c



Relationship between landslide occurrence and r_c

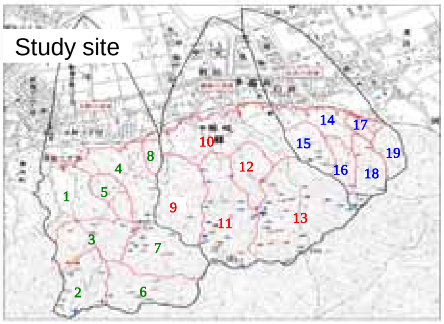
C-SLIDER method

Catchment scale shallow landslide-induced debris flow risk evaluation method



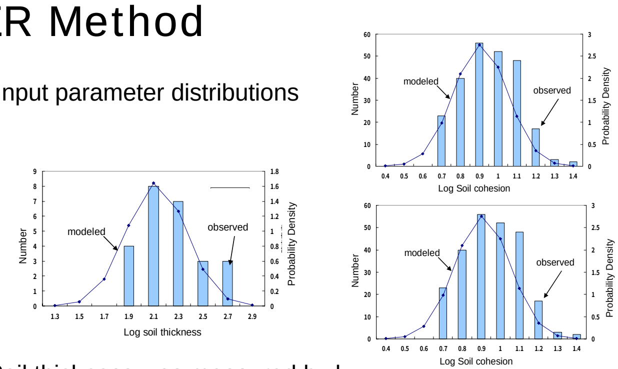
Although H-SLIDER method successfully identified shallow landslide location, we need lots of time and budget to obtain adequate underground information for H-SLIDER .So, we proposed stochastic method for evaluation of shallow landslide induced debris flow susceptibility using H-SLIDER concepts and Monte-Carlo simulations

Test of C-SLIDER Method



The study was conducted in Niihama Ehime, Japan. In Aug. and Sep. of 2004, 108 shallow landslides were triggered in this area (3.2 km^2). We divided 19 sub-catchment in this area. We evaluated shallow landslide risk of each subcatcment

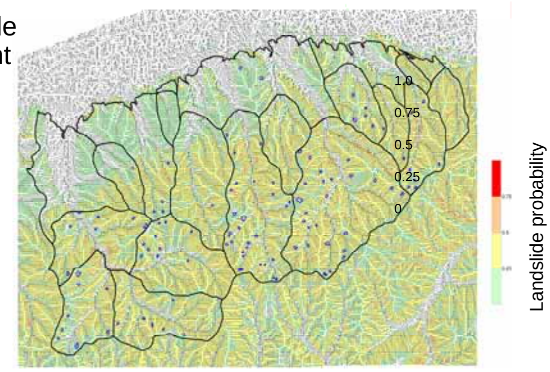
Input parameter distributions



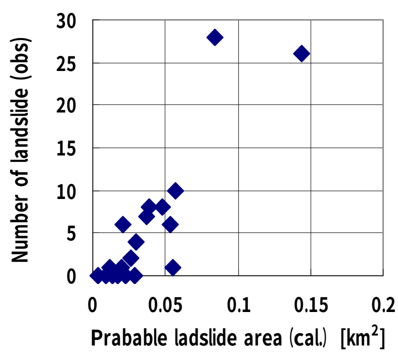
Soil thickness was measured by knocking pole test. Soil strength (cohesion and friction angle) was estimated by results of knocking pole tests and model by Wakatsuki et al.(2007). Soil K_s was used dataset by Hendrayanto (1999). These data showed that both soil thickness, soil strength and saturated conductivity-frequency relationship could be described by log-normal distribution model.

Applicability of C-SLIDER

Calculated probable landslide areas of each sub-catchment was strongly correlated with numbers of shallow landslides. This means that C-SLIDER method successfully evaluated catchment scale risk of shallow landslide and debris flow triggered by shallow landslide..



Spatial variability of landslide susceptibility



Relationship between number of landslide and probable landslide area calculated by C-SLIDER method of each catchment

Conclusions

Here we propose a new stochastic method for evaluation of shallow landslide induced debris flow susceptibility combined simple hydrological model, the infinite slope stability model and soil thickness-frequency relationship model. Our method successfully identified shallow landslide location triggered by the heavy rainfall of June, 1999.