Risk Index of Debris Flow Damage for Hydro- and Geographic Characteristics of Debris Flow with Bayesian Method

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ABSTRACT

Recent abnormal climate change induces localized heavy rainfall and extreme disasters such as debris flow near urban area. Thus many researches have been conducted to estimate and prevent, especially in focus of physical behavior of debris flow. Even though it is hardly to consider overall related parameters to estimate the extent and degree of directly or indirectly damages due to debris flow. Those analytic restraint would be caused by the diversity and complexity of regional topographic and hydrodynamic characteristics of debris flow inside. We have utilized the Bayesian method to compensate the uncertainty due to the complex characteristics of it after analyzing the numerical results from FLO-2D and field measurement data. Revised values by field measurements will enhance the numerical results and the missing parameters during numerical simulation will be supplemented with this methodology. As a final outcome in this study, the risk index of debris flow damage will be suggested to provide quantitative estimation in terms of hazard protection including the impact on buildings, especially in inner and outer of urban area.

Keywords : debris flow, Bayesian analysis, FLO-2D, risk index of debris flow (RID)

1. Introduction

Disasters related to debris flow become occasionally occurred because of many natural and artificial causes such as abnormal rainfall intensity and land development. And the damage caused by debris flow has to be predicted and prevented for loss of economic and life. Most studies have focused to figure out hydrocentrated flow motion itself. Even it contains specific parameters which are hard to define precisely but even affect severely the damage propagation. In this study, it could be slightly resolved the uncertainty of motion of debris flow by combining simulation results from FLO-2D with Bayesian method. This analysis method is included the process that the results of FLO-2D is modified to be similar the observed data of real debris flow. It is necessary to improve simulated data, due to the behavior of debris flow should consider a lot of factor about topography, hydrodynamic characteristics and so on. Accordingly, this process is capable of overcoming the limitation of simulating debris flow by using Bayesian analysis. Finally we suggested the risk index due to debris flow considering the effect of hydrodynamic and geographic characteristics in terms of propagation length, velocity and impact on the building if exists.

2. Bayesian analysis

In general, Bayesian method can be explained as a kind of system to ratiocinate the probability of specific event based on the prior experience and present evidence as shown in Fig. 1.

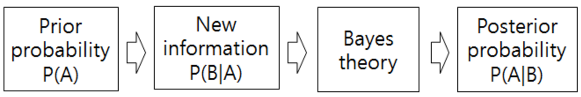


Fig. 1 Process of fundamental Bayesian method

In Fig. 1, the prior probability is represented as the simulated results by FLO-2D, the new information is set as the actual measured values of debris flow and the posterior probability can be the calculated result. Utilizing this property of Bayesian method, the propagation length and velocity of debris flow which are not able to consider with numerical simulation, FLO-2D, can be quantitatively estimated. As a result from this procedure, reducing the uncertainty of estimation would be obtained. In this study, the propagation length of debris flow was calculated as Eq. (1) and (2) as presented below: Average of posterior probability :

3. Numerical simulations with FLO-2D

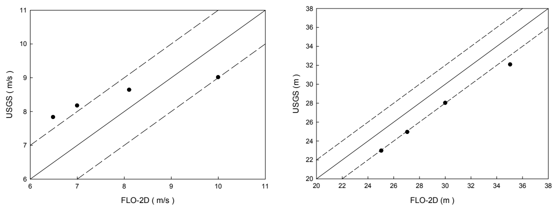
We have utilized the FLO-2D, which is recommended

$$\frac{\text{Average of prior probability} \times (1/\text{Varience of prior probability}) + \text{Average of New information} \times (1/\text{Varience of New information})}{(1/\text{Varience of prior probability}) + (1/\text{Varience of New information})} \quad (1)$$

Variance of posterior probability :

$$\frac{1}{(1/\text{Varience of prior probability}) + (1/\text{Varience of New information})} \quad (2)$$

by FEMA to simulate hyperconcentrated sediment flows such as mud and debris flow. As the first step, it has to figure out that it is verified to simulate debris flow we are interested in. For this step, the comparison between numerical results and well designed experiments conducted by USGS (Iversion, 2010). As show in Fig. 2, it is found good agreement between them almost within 10 % error boundaries, which means that FLO-2D can be satisfactorily reflective of physical behavior of debris flow. Thus we conducted various numerical simulations to investigate total amount of debris flow according to Table 1.



(a) Propagation velocity (b) Overall propagation length

Fig. 2 Comparison between numerical results from FLO-2D and experimental data by USGS (Inversion, 2010)

The study area is consisted of the side-slope hill and flat wide surface at the toe of hill. The slop of hill was 31 degree and the initial motion of debris was started at the height of 80 m.

Table 1. Numerical experiment cases with FLO-2D

Parameter	Range
Initial debris volume	500 ~ 5,000 m^3
Slope angle	-3 ~ 5 ˚

4. Result

In order to visualize numerical results after analyzing with Bayesian method, total amount of debris flow was linearly interpolated as shown in Fig. 3. Also, the probability of occurrence of debris flow was considered when we categorized them as minimum, maximum and average values.

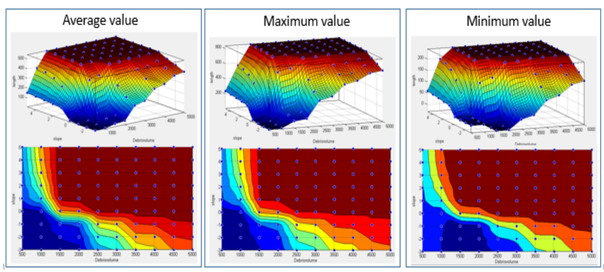


Fig. 3 Results for propagation length of debris flow using Bayesian method

It was found that we could include the effect of missing parameters which have not been considered during numerical simulation with FLO-2D when frequency of occurrence and field measurements about overall propagation length were applied. Risk index of debris flow will be presented after integration of results from this study on the propagation problem and consequential damage such as the impact on buildings. One numerical oddity was observed when the total amount of debris flow becomes less than 1,500 m3 (approximately 3,500 tons) after analyzing the effects of the propagation length and slope of sidehill, which is that final results became dependent on numerical simulation by FLO-2D.

5. Conclusion

We suggested the risk index of debris flow considering simultaneously the effects of hydrodynamic and topographic characteristics. To identify such effects, the Bayesian method was employed when calculating the overall propagation length of debris flow occurred on slope-side topography. Risk index of debris flow damage, especially on the impact on building, was presented to estimate the damage severity level in urban area. It would be possible to estimate approximately the propagation length, velocity and impact on buildings after gross approximation of amount of debris flow and slope of hill at the target urban region. Also, various significant parameters such as viscosity, yield stress of debris flow would be appointed to present the uncertainty analysis. Those entire results would be hopefully applied for the prevention on debris flow in urban area .

▌References ▌

[1] Iverson, R. M., Logan, M., LaHusen, R. G., & Berti, M., "The perfect debris flow? Aggregated results from 28 large-scale experiments", Journal of Geophysical Research: Earth Surface, 2010, 115.

[2] Jun Seon Lee, Chang Geun Song, Hong-Teak Kim, Oh Seung Oh Lee., "Uncertainty of the Estimation of Debris Flow Using Bayesian Analysis", AOGS2015, Singapore, 2015.

[3] O'Brien, J. S., "FLO-2D user's manual, version 2006.01. FLO Engineering: Nutrioso", 2006.