A Method for Estimating Maximum Damage Caused by Sediment Disaster by Surveying with Artificial Satellite SAR Imagery

Shin-ichiro HAYASHI[1*], Shin'ya KATSURA[1], Mio KASAI[1], Nobutomo OSANAI[1], Takashi YAMADA[1], Tomomi MARUTANI[1], Tomoyuki NORO[2] and Joko KAMIYAMA[2]

[1] Research Faculty of Agriculture, Hokkaido University, Japan
[2] National Institute for Land and Infrastructure Management, Japan
[*]Corresponding author. E-mail: shayashi@cen.agr.hokudai.ac.jp

INTRODUCTION

In a recent prompt disaster survey for sediment disaster, artificial satellite SAR imagery, which can be obtained even during bad weather and night conditions, was used extensively to detect large-scale landslides and landslide dams. If the maximum damage caused by a sediment disaster (hereafter "maximum damage") can be estimated directly by surveying with SAR imagery, the method may be useful for reducing the time required to determine the necessary resources for risk management. In this paper, we propose a method for estimating maximum damage by calculating an index pertaining to sediment movement from the result of a survey implementing SAR imagery. Moreover, we evaluate the applicability of the method by comparing the estimated maximum damage with the actual damage.

METHOD

The procedure of the method used to estimate maximum damage is shown as **Fig. 1**. The area and location of landslides were estimated from the result of surveys implementing SAR imagery. The volume of sediment movement was calculated by the Guzzetti equation (Guzzetti *et al.*, 2009; equation 1) from the area of landslides:

$$V = 0.074A^{0.175} \qquad (1)$$

where, V is volume of sediment movement (m^3), A is area of landslide (m^2)

The relative height of the sediment movement can be measured on a map based on the locations of landslides. From the volume and relative height, sediment movement magnitude (SMM; Uchida *et al.*, 2005) was calculated by equation 2:

$$SMM = log_{10} \sum_{i=1}^{n} (V_i \times H_i) \qquad (2)$$

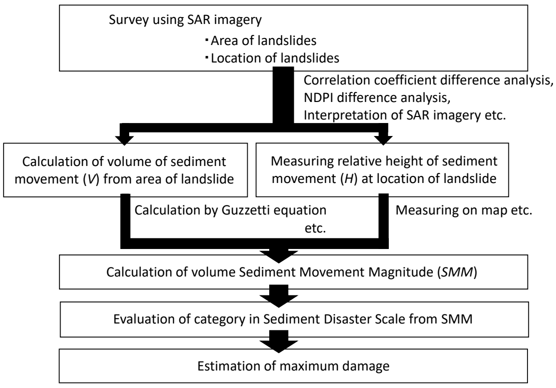

Fig. 1 Procedure of estimation of maximum damage from surveying with SAR imagery

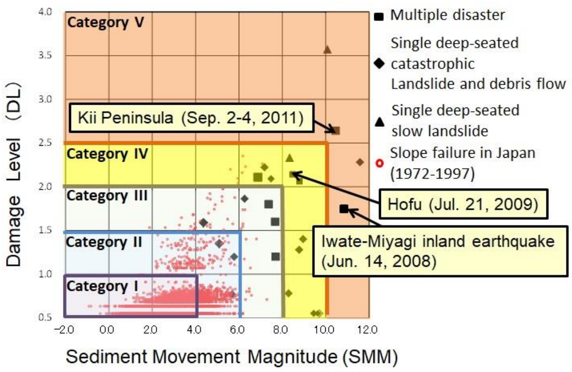

Fig. 2 Evaluation method of Sediment Disaster Scale (Based on Hayashi *et al.*, 2015)

where, *SMM* is sediment movement magnitude, *V* is volume of sediment movement (m^3), and *H* is relative height (m). The maximum damage was estimated using the Sediment Disaster Scale (SDS; Hayashi *et al.*, 2015, DL; Kojima *et al.*, 2009; **Fig. 2**). Disasters are divided into five categories of SDS based on SMM.

RESULTS

Several examples of the result of survey using SAR imagery to detect large-scale landslides and landslide dams are included in this section. The results of correlation coefficient difference analysis (CCDA) and NDPI difference analysis (NDPI) applied to the areas affected by the Iwate-Miyagi inland earthquake and the disaster in Hofu city (Hayashi, *et al.*, 2012) and the interpretation of a high-resolution SAR imagery to detect landslide dams in the Kii Peninsula that was affected by Typhoon Talas (Hayashi *et al.*, 2013) were used to estimate maximum damage. Then, we compared the estimated maximum damages with the evaluated actual damages (**Fig. 2**) by SDS based on records of the disasters (**Tables 1 to 3**).

Table 1 SMM calculated by results of CCDA and NDPI

Name of disasters	Analysys method	Area of landslide per one landslide (m^2)	Volume of landslide per one landslide (m^3)	Provisional relative height (m)	Number of detedted landslide	SMM
Iwate-miyagi inland earthquale	CCDA	40,000	348,513	100	13	8.66
	NDPI	62,500	665,668	100	9	8.78
Hofu	CCDA	40,000	348,513	100	26	8.96
	NDPI	40,000	348,513	100	24	8.92

Table 2 SMM calculated by result of interpretation of SAR imagery

Name of landslide	Area (ha)	Volume of sediment movement (m^3)	Relative height (m)	SMM
Tsubonouchi①	2.0	127,563	180	7.36
Tsubonouchi②	11.8	1,672,864	180	8.48
Tsubonouchi③	5.2	509,843	200	8.01
Ui	8.7	1,075,312	230	8.39
Nagatono	19.5	3,465,628	440	9.18
Akadani	28.2	5,916,882	570	9.53
Kuridaira	33.7	7,661,170	330	9.40
Mikoshi	6.3	673,404	180	8.08
All				9.91

Table 3 Comparison of SMM and SDS category of actual damage and result of estimation

Name of disaster	Analysys method	Actual damage		Result of estimation	
		SMM	Category	SMM	Category
Iwate-miyagi inland earthquale	CCDA	10.37	Ⅴ	8.66	Ⅳ
	NDPI			8.78	Ⅳ
Hofu	CCDA	8.48	Ⅳ	8.96	Ⅳ
	NDPI			8.92	Ⅳ
The Great Flood in the Kii Peninsula	Interpretation	10.46	Ⅴ	9.91	Ⅳ

CONCLUSIONS

By using several results of surveys performed using SAR imagery, we proposed a method to estimate maximum damage based on SDS and evaluated the applicability of the method. According to the results shown in **Tables 1 to 3**, the method can 1) be valid, because the SMM and SDS category estimated by the method were almost the same as those of the actual damage, and 2) could underestimate the maximum damage if a huge landslide (i.e., Aratosawa landslide, approximately $7\times10^7 m^3$) existed in the SAR imagery.

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