The recent decrease in debris flow in Tansan-dani gully at Mt. Unzen

Jihyeok Park [1], Yoshinori Shinohara [1], Hotta Norifumi [2], Christopher Gomez [3]*

[1] *Faculty of Agriculture, University of Miyazaki, Japan*
[2] *Graduate School of Agricultural and Life sciences, University of Tokyo, Japan*
[3] *Graduate School of Maritime Science, Kobe University, Japan*

Introduction

At Mt.Unzen, over 25-years have passed since the 1990-1995 eruption and, debris flows are still being observed in the Tansan-dani gully, a tributary of the Mizunashi-gawa river. Although there are many studies that examine characteristics of debris flow in this area, they had focused on debris flow before 2000 when debris flow had been frequency occurred. However, the scale and frequency of debris flow over time are unclearly understood after 2000.

The objective of this study was to clarify the trend of debris flow occurrence in the Tansan-dani gully since 2000. This would be important for comprehensive understanding of the debris flow and sediment management in this area.

Materials and Methods

The present study was conducted in the Tansan-dani gully, at Mt.Unzen (Fig. 1A). We focused on the period of 2000-2020. We installed more than four time-lapse cameras (TLC) and captured images at an interval of 1-min in the rainy seasons (i.e., generally from June to October) during the period of 2016-2020 (Fig 1B). We set two cameras to be able to view upstream and downstream at each monitoring point.

The captured images were defined as "debris flow" when the flow surges involving sediment entrainment and deposition were observed, and "surface runoff" was defined when runoff exceeding 30-minutes was observed. Also, we extracted 14 debris flow data from previous studies for the period 2000-2015.

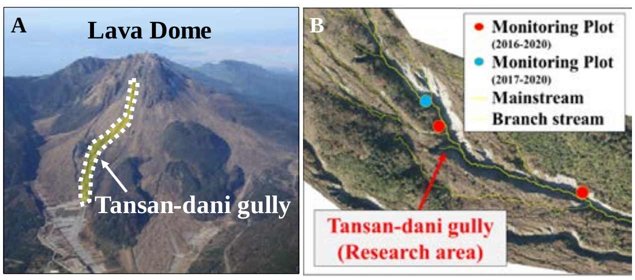

Figure 1. Mt.Unzen and Tansan-dani gully

The rainfall data come from the JMA (Japan Meteorological Agency) Unzen-dake station, 4 km to the West of the Tansan-dani gully. The 10-minute rainfall data were used to identify and analyze the debris flow imaged from the TLC, and for the longer time-span (2000 to 2020) 1-hour rainfall data were used for the analysis of antecedent precipitation indices (APIs). The rainfall events were separated with 24-hour non-rainfall period for TLC and APIs analysis.

To clarify the trend of debris flow occurrences, we calculated APIs with various Half-Life Times (HLTs) for all rainfall events during the period of 2000-2020 using the following equation:

$$\boldsymbol{X(M,t) = X(M,t-1)e^{\alpha} + R(t)e^{\alpha/2}} \quad \textbf{(1)}$$

$$\boldsymbol{\alpha = ln(0.5)\,/M} \quad \textbf{(2)}$$

where $X(M,t)$ is the APIs, $R(t)$ is the 1-hour rainfall at time t-hours ago, α is the reduction coefficient and M is the HLTs.

$$\boldsymbol{E(M,t) = X(M,t)/N_{max}(M)} \quad \textbf{(3)}$$

where $E(M,t)$ is the current ratio of API to non-triggering API maximum for HLTs, and $N_{max}(M)$ is the non-triggering APIs maximum values for various HLTs from 2016 to 2019. In this study, we calculated 401 HLTs between 0.1-hour and 2784-hour [1] for all events from 2000 to 2020. Based on the $E(M,t)$ value, the difference between triggering event and maximum of a non-triggering event can be determined from these values.

We assume that if $E(M,t)$ exceeds 1, it is triggering an event, otherwise it is classified as a non-triggering event. Subsequently, the threat score, which is known as the critical success index, was used as the primary variable for verifying APIs analysis in this study and defined by:

$$\boldsymbol{TS = \frac{TP}{TP+FP+FN}} \quad \textbf{(4)}$$

where TP is the number of correct predictions, FP is the number of false alarm, and FN is the number of incorrect predictions.

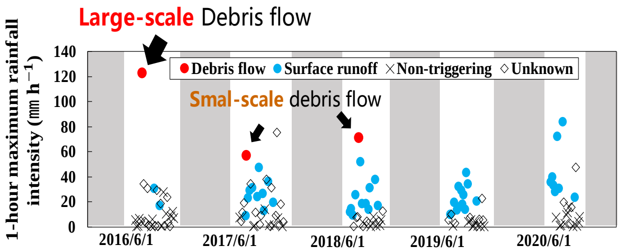

Figure 2 1-hour maximum rainfall intensity of rainfall events each sediment discharge from 2016 to 2020.

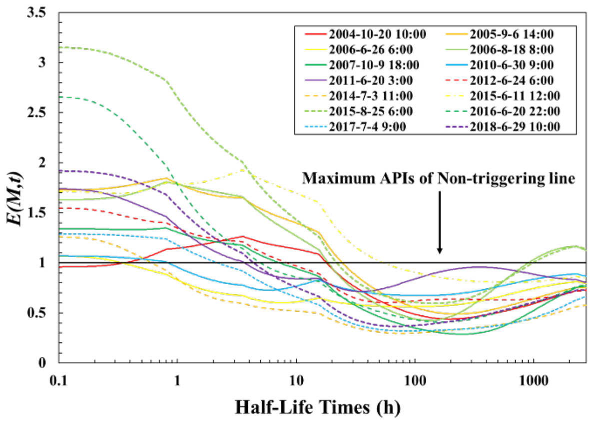

Figure 3 $E(M,t)$ of HLTs for triggering events from 2000 to 2019

Result and Discussion

For the period 2016-2020 a total of 3 debris flows and 64 surface runoff were detected (Figure 2), with the first debris flow of 2016 being prior to the TLC installation. The debris flow that occurred in 2016 reached the check dam past the Tansan-dani gully. In contrast, debris flows in 2017 and 2018 stopped within the Tansan-dani gully. Although the 1-hour maximum rainfall of the three events in 2020 was over 60 mm, debris flows did not occur for the three events.

All the debris flows that occurred at Mt.Unzen from 2000 to 2019 exceeded the non-triggering maximum APIs in the HLTs range of less than 1-hour (Figure 3).

Especially, when HLTs range 0.1-0.33 and 0.3-0.66, the threat score was 0.928 (Figure 4). This means that debris flow occurrence in Tansan-dani gully is the result of rainfall with short HLTs.

Figure 5 shows $E(M,t)$ of five rainfall events in 2020 with values exceeding 1 for some HLTs. Three events exceed the $E(M,t)$ of 1 in HLTs range of less than 1-hour. This indicates that the threshold of $E(M,t)$ between triggering and non-triggering events in 2020 has become higher than threshold before 2019.

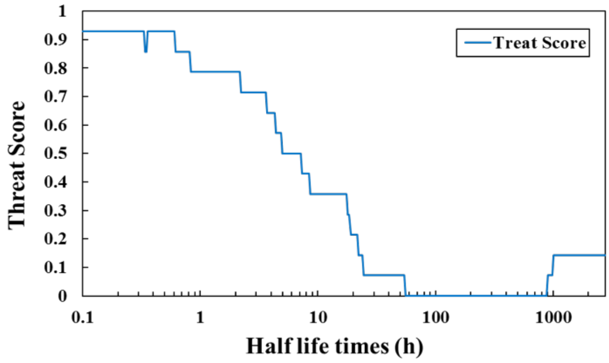

Figure 4 The threat score of each HLTs

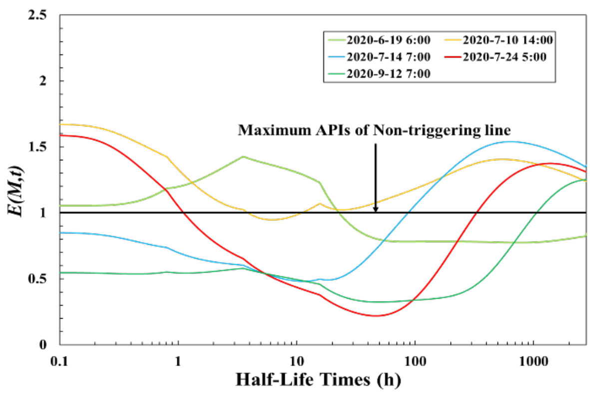

Figure 5 $E(M,t)$ of 401 HLTs for five events in 2020

The recent changes in the occurrence of debris flow may be because of 1) changes in material in the gully suggested by [2], and 2) terrestrial changes like the development of lateral erosion in the gully. Also, as we have used rainfall data 4 km away from the Tansan-dani gully, our results may be affected by spatial variability of rainfall distribution.

Acknowledgement

This study was financially supported by a research project funded by the MLIT.

References

[1] Kosugi, K. 2015. Evaluation of storm events triggering slope failures. Journal of Japan Society of Erosion Control Engineering. Vol.67, No.6, pp.12-23.

[2] Gomez, C., Hotta, N., Shinohara, Y., Tsunetaka, H. 2019. Change at Unzen Volcano & Impact on Lahar Triggering and Flowage. Conference of Japan Society of Erosion Control Engineering.