Interaction between riverbed condition and characteristics of debris flow in Ichino-sawa subwatershed of Ohya-kuzure landslide, Japan

Haruka Tsunetaka[1], **Norifumi Hotta**[1],**Fumitoshi Imaizumi**[2], **Yuichi S. Hayakawa**[3], **Noriki Yumen**[2]

1. Life and Environmental Sciences, University of Tsukuba, Japan (tsunetakaharuka@gmail.com).
2. Graduate School of Agriculture, Shizuoka University, Japan. 3. Center for Spatial Information Science, The University of Tokyo, Japan.

1. Introduction

Large-scale sediment movements, such as deep-seated landslides, induce immediate damage in the form of sediment disasters downstream and produce a large amount of unstable sediment upstream. Most of the unstable sediment residing in a mountain torrent is discharged as debris flow. Hence after the occurrence of large-scale sediment movement, debris flows have a long-term effect on the watershed regime. However, the characteristics of debris flow in upstream areas are not well understood, due to the more complicated topographic and grain-size conditions compared to those in the downstream areas. This study was performed to reveal the relationship between such riverbed condition and the characteristics of debris flow by field observations.

6. Conclusion

The magnitude and occurrence of debris flow in the upstream area are not only dominated by rainfall index as the riverbed condition (i.e., grain-size and deposit depth distribution) has an effect on the form and duration of debris flow. Moreover, the riverbed condition succeedingly changes, thereby surges repeatedly flows down during the rainfall event. Consequently, sediment yield and magnitude of the debris flow event differ as the preceding surges have an influence on the succeeding surges through the change in riverbed condition.

2. Study site and Method

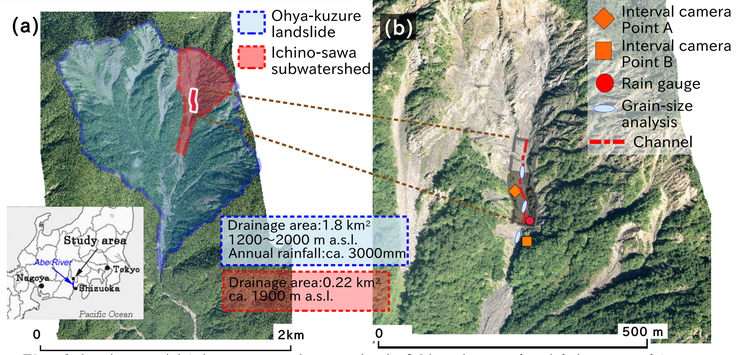

Fig. 1 Study site. (a) Ichinosawa subwatershed of Ohya-kuzure landslide, central Japan (N 35° 18' 31", E 138° 18' 55"), (b) The location of the monitoring and survey area.

・The basin experienced a deep-seated landslide about 300 years ago and is currently actively yielding with a clear annual cycle.

Fig. 2 Changes of deposited sediment in Ichino-sawa subwatershed through debris flow events.

・During the winter season, sediment is deposited on the valley bottom by freeze-thaw and weathering (**Fig. 2a**). In summer season, the deposited sediment is discharged incrementally by debris flows related to storm events (**Fig 2b**).

・Channel slope is ca. 30 degrees (**Fig. 3**)

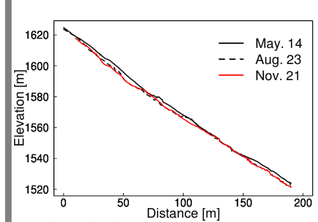

Fig. 3 Channel profiles in 2012.

・Topographical surveying and grain-size analysis were performed several times between November 2011 and November 2014.

→ Point cloud data were acquired during the topographical surveying with the use of a terrestrial laser scanner, and used to create a high-resolution digital elevation model (10 cm).

→ Grain-size analysis was conducted in the upper, middle, and lower parts of the study site. Line-grid method was employed for the in situ analysis (**Fig. 1b**).

・Debris flow occurrence and flowing down form were monitored by interval cameras (interval is 10s, 15s, and 1hour). Rainfall was observed during the summer season for comparison with the debris flow occurrence and magnitude (**Fig. 1b**).

3. Relationships between debris flow and rainfall

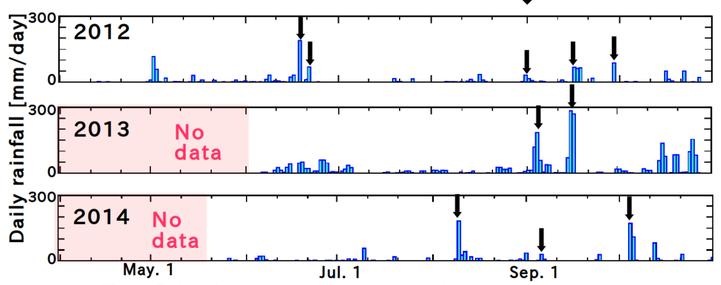

Fig. 4 Daily rainfall and occurrence of debris flow events.

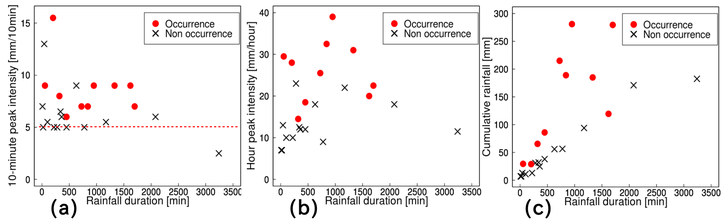

Fig. 5 Relationships between the rainfall duration and the rainfall index.
(a) 10-minute peak intensity, (b) Hour peak intensity, (c) Cumulative rainfall.

・10 debris flow events occurred during the study period (**Fig. 4**).
・All debris flow caused by rainfall events exceeding 5 mm/10 min (**Fig. 5a**).
・In contrast, hour peak intensity, cumulative rainfall and rainfall duration show no influence on the occurrence (**Fig. 5bc**).
・However, rainfall events exceeding 5mm/10min did not necessarily cause debris flows.

→ Occurrence of debris flow was not dominated only by the rainfall intensity and duration.

4. Relationships between debris flow and riverbed condition

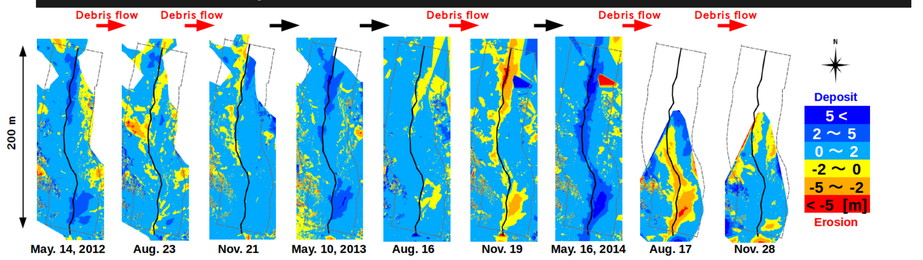

Fig. 6 Time series changes of distribution of erosion and deposition area.

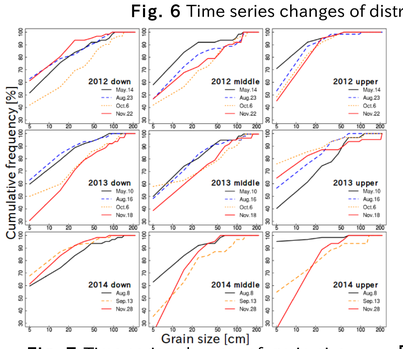

Fig. 7 Time series changes of grain-size distribution.

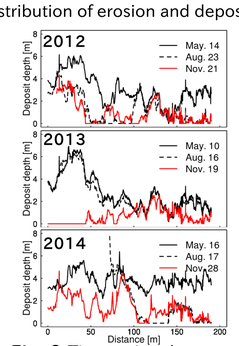

Fig. 8 Time series changes of deposit depth in the channel.

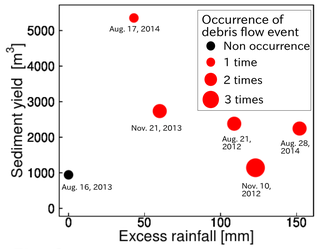

Fig. 9 Relationships between the excess rainfall (threshold is 5mm/10min) and sediment yield. Size of point means the number of times of occurrence of debris flow event during the period of topographical surveying. Sediment yield calculated at the part of shade Fig. 1b.

・Rainfall events altered the distribution of erosion area and grain-size (**Fig. 6,7**).
・More significant changes were detected after the debris flows (**Fig. 6,7**).
→ The riverbed condition (i.e., grain-size distribution (**Fig. 6**), deposit depth (**Fig. 8**)) were significantly different before and after flowing down of the debris flow.
・In addition, the pattern of changes in the riverbed condition were spatiotemporally uneven (**Fig. 6,7,8**).
→ Several debris flows of different magnitudes occurred during the study period.
・Moreover, sediment yield was not dominated by excess rainfall and the number of times of occurrence of debris flow events (**Fig. 9**).

→ These results suggest that the magnitude of the debris flows were different according to the influence of riverbed condition.Thus, in upstream area, magnitude of the debris flow event cannot be predicted only by rainfall index.

5. Characteristics of debris flow in upstream area

Fig. 10 Changing form of debris flow surge and riverbed condition on Aug. 10, 2014. (a) Before the debris flow event, (b) the situation flows down of surge, (c) After deposit surge flows down, (d) After erosion surge flows down.

・Different forms of debris flow surges observed at point A (**Fig. 1b**) during the rainfall events (**Fig. 10**).
→ Surges not only induced erosion deposited sediment but also suspended and deposited sediment.
・Occurrence of these surges corresponded to the peak of 10-minute rainfall intensity (**Fig 11**).
→ The riverbed condition successively changed during the rainfall event thereby surges repeatedly flowed down.
・Form and duration of the surge differed nevertheless cumulative rainfall is not significantly different (**Fig. 12**).
→ The form of surges were not dominated only by rainfall condition.
→ Surge durations in the downstream area (point B) were often longer than the upstream area (point A) because of the supplied erodible sediments by suspended and deposited surges.

→ The changing of riverbed condition during the rainfall event influence the magnitude and form of the debris flow.

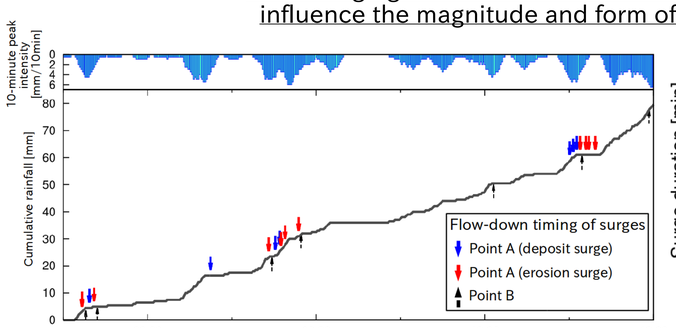

Fig. 11 The timing and form of debris flow surges on Aug. 10, 2014.

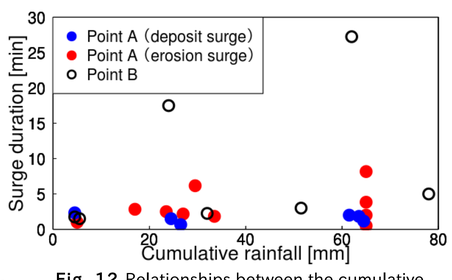

Fig. 12 Relationships between the cumulative rainfall and surge duration in the debris flow event on Aug. 10, 2014.