Probabilistic method for assessing disaster risk due to deep-seated catastrophic landslides in Japan

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INTRODUCTION

In steep mountainous regions, soil and weathered bedrock have the potential to slide simultaneously. These landslides often move rapidly, triggering debris flows and dam formation. In this paper, such landslides are referred to as „deep-seated catastrophic landslides" or DCLs. Our definition excludes slow failures of a more chronic nature, such as deep-seated chronic landslides, deep-seated gravitational creep, or rock flow.

In 2011, we classified Japan into four categories in terms of past DCL frequency and published the „Deep Catastrophic Landslide Frequency Map of Japan" (Uchida et al., 2012). We also developed a new method to estimate DCL susceptibility for many small catchments (ca. 1 km^2) over relatively large areas (ca. hundreds of km^2); the Japanese government applied this method in a nationwide DCL susceptibility assessment (Uchida et al., 2012). However, it remains difficult to assess (1) the probable scale of a future DCL and (2) the areas prone to DCLs.

METHOD

We conducted two analyses using historical landslide data. First, to develop a method for assessing the scale of future DCLs, we tested the hypothesis that the scale of a DCL should be comparable to those of past DCLs in the same region, because the scale of a DCL is strongly controlled by the geological and geomorphological setting. To test this hypothesis, we prepared a multi-temporal landslide map from a visual study of sets of stereoscopic aerial photographs of Yamanashi and Nara, Japan, from which we quantified temporal changes in the landslide size distributions for each region.

Second, to develop a simple empirical method for assessing the probability that DCL-induced sediment flows or flooding would reach a village, we examined the relationship between the distance from the DCL to the lower end of the damaged area (hereafter, the „travel distance") and the landslide size for each disaster type, such as debris flows and landslide dam breaches. A literature search identified about 300 Japanese disasters from DCLs for this analysis.

RESULTS

We found a site-specific relationship between landslide area and the frequency of DCLs, supporting our hypothesis that the scale of a DCL is comparable to those of past DCLs in the same region. We also found that DCLs have a significantly higher probability of occurrence near ancient DCL scars than far from them.

In the second analysis, we found a positive correlation between the travel distance and the area of a DCL scar, although the data were scattered (the diamonds in the small graphs in Fig. 1). Moreover, the travel distance was affected by disaster type; for example, the travel distance of disasters due to landslide dam breaches was farther than those of debris flows. Based on these findings, we proposed a probabilistic relationship between travel distance and landslide area (small graphs in Fig. 1).

DISCUSSIONS

We proposed a probabilistic method for assessing the risk of disasters due to a DCL. Figure 1 shows an example of the risk assessment results. Using the spatial pattern of ancient DCL scars mapped from stereoscopic aerial photographs and light detection and ranging (LiDAR) data (hatched area in Fig. 1), we assessed the probability of risk due to a DCL. For example, the plots of ancient DCLs (open circles in the small graph in Fig. 1a) suggested that there was almost no possibility that a DCL-induced debris flow would affect the village, although there were a number of ancient DCL scars in the basin surrounding the village. However, we found that the village could be affected by a disaster due to a landslide dam breach.

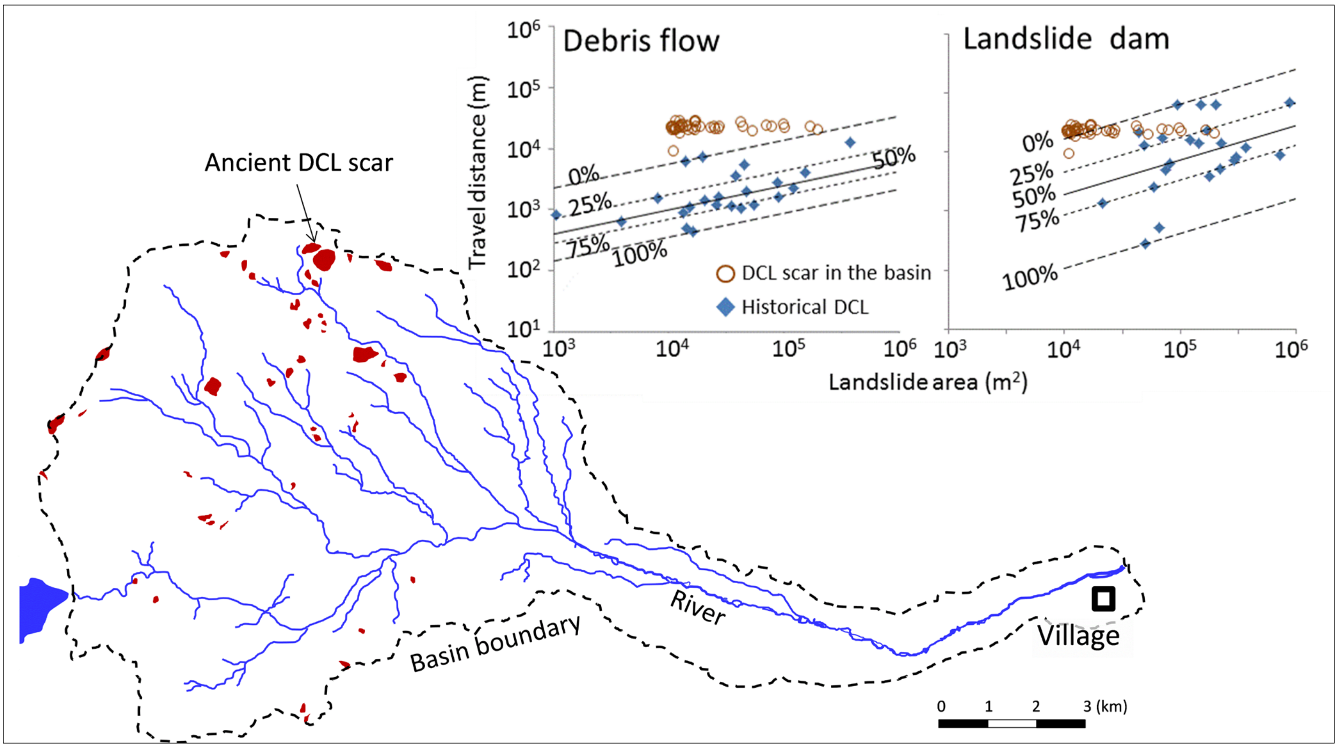

Figure 1. Example of risk assessment results. The hatched areas in the map indicate ancient deep-seated catastrophic landslides (DCL) scars. The small graphs plot the relationship between landslide area and travel distance for debris flows and landslide dams. Diamonds represent the relationship between landslide area and the travel distance of historic DCLs. Circles represent the relationship between the area of ancient DCL scars and the distance from the DCL scar to the village.

CONCLUSIONS

We showed that (1) future landslides may occur at locations close to ancient DCL scars, (2) the scale of future DCLs appear to be similar to that of ancient DCLs in the same region, and (3) the probability of risk due to a DCL can be estimated using the probabilistic relationship between DCL scale and travel distance. Based on these results, we proposed a probabilistic risk assessment method for disasters due to DCLs.

REFERENCE

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KEYWORDS

Deep-seated rapid landslide; risk assessment; Database; landslide dam; debris flow

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