Distribution of landslides triggered by Kumamoto Earthquake and subsequent sediment transport in forested and grass lands

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1. Introduction

Kumamoto Earthquake occurred on April 16th and triggered 158 sediment-related disasters in Kumamoto Prefecture, Kyushu Island, Japan. Number of casualty by these sediment disasters became 10. Furthermore landslides also occurred due to intense rainfall after the earthquake, causing various damages and casualty (Kumamoto Prefecture, 2016). Numerous landslides also occurred on hillslopes covered by forest and grassland in western Aso volcanic region. Some of the sediments from landslides are still located on hillslope and/or in-channel adjacent to hillslope, while some of sediment can be transported to further downstream by debris flow. Remaining sediment in channels possibly cause subsequent sediment disasters. Despite many researches on landslides due to Kumamoto Earthquake (Ishikawa et al., 2016; Miyabuchi, 2016), less attention was paid for distribution of landslides and remaining sediment on hillslope and channels. Therefore, the primal objectives of this study are (1) evaluating the characteristics of landslide distribution in forest and grassland, and (2) estimating the amount of sediment remaining on hillslopes and in-channels. We conducted both GIS analysis and field investigation.

2 Material and Method

2.1. Study area

We selected two watersheds: Tokosegawa-watershed (6.9km^2) and Nigorigawa-watershed (6.1km^2). They are located in western foot of central cones of Aso Volcano. Estimated maximum seismic intensity of the area was 6- to 6 + in Japanese scale. Altitude of two watersheds ranges from 277 to 1326m, and mean slope gradient is 16.7 degree. Mean annual precipitation in AMeDAS Aso-Otohime is 2889mm. High and intense precipitation occurred in Baiu season, June and July. Volcanic rock is covered by thick pyroclastic fall deposit originated from central cones (Miyabuch, 2016). Watershed land use is 54% of forest, 30% of grassland, and 16% of residential and others. Forested area is mostly dominated by Japanese cedar (*Cryptomeria japonica*) and cypress (*Chamaecyparis obtusa*). Grass land is dominated by Japanese silver grass (*Miscanthus sinensis*).

2.2 Methodology

We conducted (1) aerial photo interpretation, (2) GIS analysis, and (3) field investigation. Aerial photo taken on April 29th 2016 was used to identify landslides by the earthquake. Landslides as polygons were analyzed by ArcGIS for estimation of area, initiation altitude, geology, and land cover of each landslide. We selected 38 sites for field investigation

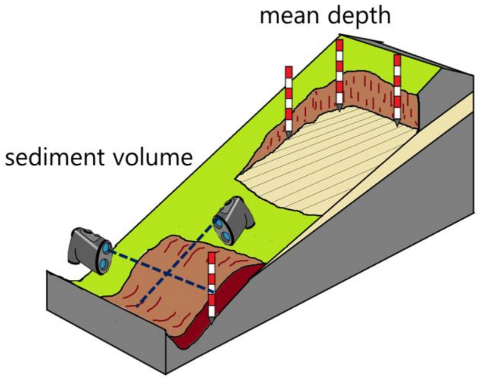

Fig. 1 Field investigation.

for estimating depth and volume landslides (Fig. 1). All of the field investigation was conducted in September 2016.

3. Results and Discussion

3.1. Landslide distribution

We identified 106 landslides in forest and 77 landslides in grassland in the study area. Mean landslide area in forested land was 1551±1708m^2, while that in grassland was 1524±2546m^2. Occupied percentage of landslides was 2.2%, which was within ranges of rainfall-induced landslides in Aso area reported by Miyabuchi et al. (2004). Greater landslides in forested area concentrated in hillslope gradient ranging from 20 to 35 degree (Fig. 2), which

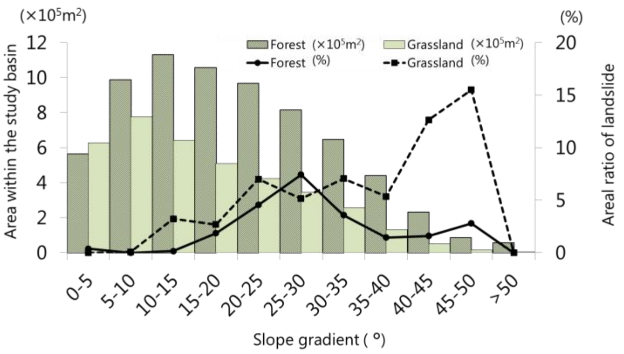

Fig. 3 Landslide distribution for different slope gradient

agrees to previous studies conducted in volcanic regions (Mandaglio et al., 2016). In grass land, percentages of landslide had occurred increased with increases in hillslope gradient. Because of root depth and cohesion of grass was weaker than that in forest, stability of hillslope against shaking by the earthquake tended to be low in grass land for increases in probability of landslides occurrence.

3.2. Sediment transport

Mean landslide depth (soil surface to failure plain) in forest and grassland was 1.9±1.6m and 1.1±0.6m, respectively. Estimated mean volumes of sediment yields based on the area and depth were 2256±2610m^3 in forest and 843±842m^3 in grassland (Fig. 3). Based on the subtraction of volume of sediment yields by remaining volume on hillslopes and in-channels was 1416±1748m^3 that corresponding to 0-1556% in forested areas. In grass lands, mean volumes of

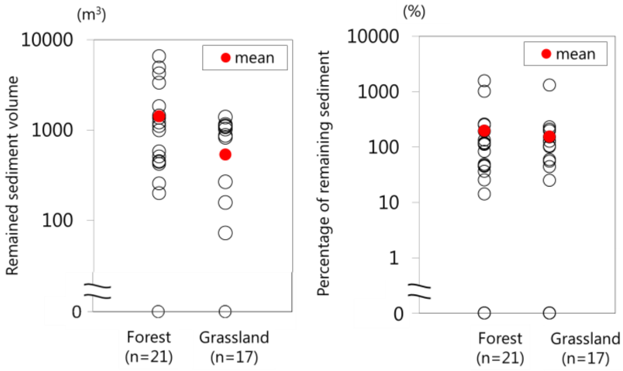

Fig. 2 Volume and percentage of sediment remaining on hillslopes and channels.

remaining sediment with percentages was 538±512m^3 with 0-1331%. High percentages of unstable remaining sediment mass occurred in greater drainage areas. This result suggested that sediment tended to be accumulated with the materials transported from upstream of channel networks. Because Benda et al. (2004) showed that sediment transport is important for sediment movement and accumulation, our finding also implied that sediment accumulations in channel networks is also important for understanding dynamics after earthquake.

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