国際共同研究（ 課題番号： 29W-02 ）

課題名：Do earthquake fissures predispose slopes to landslides and subsequent sediment movement?

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研究期間：平成 29 年 6 月 1 日 ～ 平成 31 年 3 月 31 日

研究場所： 斜面災害研究センター，熊本県南阿蘇村

共同研究参加者数： 12 名（所外 6 名，所内 6 名）

・大学院生の参加状況： 6名（修士 3 名，博士 3 名）（内数）

・大学院生の参加形態 [研究打ち合わせ及び現地調査・計測の参加，研究成果の紹介および議論]

研究及び教育への波及効果について

Six graduate students participated in this project, three of them from graduate school of science, Kyoto University, and three from Tokyo University of Agriculture and Technology. Through involving this project, the students elevated their understanding not only on earth surface processes, but also on the methodology in conducting scientific research.

研究報告

(1) 目的・趣旨

Our research objective were to: (1) assess the distribution and depth of fissures caused by the earthquakes in selected sites near Mt. Aso; (2) ascertain whether fissures concentrate enouogh subsurface water to trigger new landslides; (3) assess vulnerability of future debris flows in the affected region; and (4) quantify the differences in landslide occurrence and sizes between forested and grassland sites and estimate the impacts of these ground disturbances on future ecosystem services in the region.

(2) 研究経過の概要

During a number of field trips to the affected area, monitoring sites were selected and tensiometers and TDR's were installed at various soil depths in and between earthquake fissures in a 6 × 20 m area along the ridgeline of the grassland site. Comparisons of earthquake-induced landslides between forested and grassland hillslopes were conducted in two catchments: Tokosegawa (6.9 km^2) and Nigorigawa (6.1 km^2) along the western foot of the central cones of Aso Volcano where some of the highest shaking intensity occurred. Landslide inventories were conducted using aerial photograph interpretation, GIS analysis, and field investigations, and the resulting sediment deposits triggered by the 2016 Kumamoto earthquake were also measured.

(3) 研究成果の概要

The subsurface pore pressure fluctuations in and adjacent to the fissures during the period from 27 June 2018 to 23 September 2018 were highly dynamic in various layers of the volcanic soil. As expected, pore water pressure near the surface responded rapidly to rainfall inputs, with positive or nearly positive pore pressures measured at the 0.5 m depth of the lower elevation fissure during July 3, 5-7, and 27 and during September 1-2, 8-9, and 20-22. One of the most interesting responses occurred during the extended and moderate intensity Baiu rainfall from 5-8 July 2018; 207 mm of rain fell during this period. In this rainfall event, pressure head monitored in the second andisol layer of fissure F2 initially increased from -20.2 to +1.9 cm H_2O. The corresponding initial pore water pressure in the first andisol layer of the uppermost ridgeline (R1) increased from -34.8 to -4.1 cm H_2O; in the second andisol layer of R1, pore pressure initially increased from -20.4 to -3.8 cm H_2O (Figure 1). The initial increase of pressure head with depth in the second andisol layer of the upper ridge (R1) was delayed by about 3 hours compared

to the same andisol layer of F2; however, shortly after the peak hourly rainfall (33.8 mm h^{-1}) on 7 July, pore pressure at R1 declined to +14.3 cm H_2O compared to +4.6 cm H_2O at F2 (both recorded in the second andisol layer).

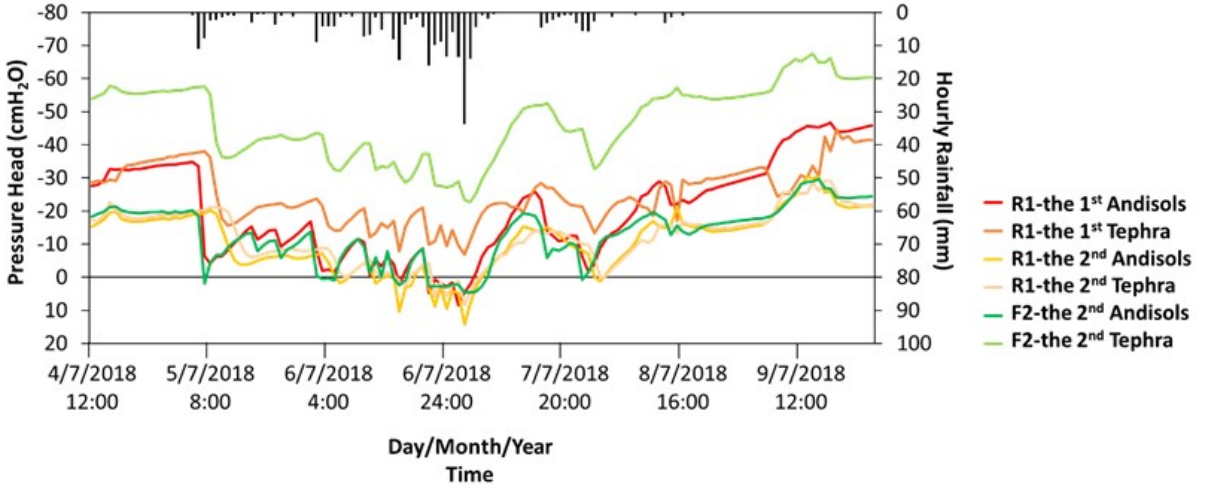

Figure 1. Pore water pressure response at R1 and F2 during rainfall from 5 to 8 July 2018.

Of the 190 earthquake-initiated landslides identified in the two catchments, more (per unit area) occurred in grasslands than in forests, likely owing to greater root reinforcement of trees. Most landslides initiated on ridgelines and/or convex/planar hillslopes, travelled short distances, and did not evolve into debris flows. The ratio of total area occupied by landslides for a given range of slope gradient in the catchments increased from 3.2% on gentle grassland slopes (10-15°) to 15.5% on steep (>45°) slopes, whereas the maximum landslide-area ratio in forest sites (7.4%) occurred on relatively gentle slopes (25° to 30°). Our findings show that land cover significantly affects landslide characteristics and in-channel sediment accumulations.

(4) 研究成果の公表

***Refereed Journal Publications*:**

R.C. Sidle, T. Gomi, M. Akasaka, and K. Koyanagi. 2018. Ecosystem resetting following the 2016 Kumamoto earthquake – implications for sustainability. Ambio 42(6): 721-734, doi:10.1007/s13280-017-1005-8.

K. Koyanagi, T. Gomi, and R.C. Sidle. 2019. Characteristics of landslides in forests and grasslands triggered by the 2016 Kumamoto Earthquake. Earth Surf. Processes & Landforms (in revision).

***Presentations at Conferences with Published Abstracts*:**

R.C. Sidle, T. Gomi, M. Rajapbaev, and N. Chyngozhoev. 2017. Can fissures predispose hillslopes to landslides? – Evidence from Central and East Asia. Geophysical Res. Abstracts, vol. 19, European Geophys. Union.

Y. Arata, T. Gomi, R.C. Sidle, G. Wang, C.-W. Chiu, and K. Koyanagi. 2018. Hydrogeomorphic characteristics of fissures developed during 2016 Kumamoto Earthquake. INTERPRAEVENT Intl. Symp. October 2018, Toyama, Japan.