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研究課題名（和文）A new method by exploring responses of mountain slopes to river incision for predicting potential landslide sites for hazard mitigation: A case of Shirakami-Sanchi, Japan

研究課題名（英文）A new method by exploring responses of mountain slopes to river incision for predicting potential landslide sites for hazard mitigation: A case of Shirakami-Sanchi, Japan

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研究成果の概要（和文）：地すべり多発地帯である白神山地において、詳細な地形データを用いた地形の解析によって、地すべり地形と変位を同定し、地質踏査によって地質構造を検討した。大川地すべり地において、多時期の地形データで比較した結果、水平変位量は0.1-9.7mがあった。地すべりは、大きく北と南のブロックに分けられ、それぞれ南西と西北への変位が進行した。南ブロックにおいて、植生を載せたまま滑り落ちた島状土塊がみられ、この土塊は8年間にかけて約7m移動している。変位量が最も大きい所は、二次滑落崖での3-9mと末端部での2-8m。河川が右岸に集中したことにより末端部の浸食が進行し、地すべりが再活動化した可能性がある。

研究成果の学術的意義や社会的意義
気候変動や地震により大規模な地すべり・崩壊が多発すれば、土砂災害とともに森林生態系も大きな影響をうけることが懸念される。本研究は、地すべり斜面の変動に関する定量的なデータが少ない白神山地において、詳細な地形データに基づく地すべり発生機構や斜面動態の計測に基づき解析を行った。山岳地の地形発達において、河川プロセスがマスムーブメントの発生場に対し重要な役割を働いていることを明らかにすることによって、より詳細かつ実態的な地すべり発生機構の解明に資するものである。本研究の成果も環境保全に資するところもあると考える。

研究成果の概要（英文）：Mt. Shirakami shows a typical fluvial landscape where many landslides are distributed. Field geological and geomorphological surveys, mapping of landslides using aerial photos and 1 m LiDAR DEM were conducted. At the Okawa landslide, comparison of the topography of 2017 and 2008 suggests horizontal displacements range from 0.1-9.7 m. At the landslide body of the northern part the computed vectors show a southward movement. The longitudinal displacement for a flat, terrace-like topography within the landslide body of the southern part was computed of ~7 m. Active displacements were constrained at the secondary and side scarps of 3-9 m and the edges of toes of 2-8 m, where the retreating movements are identified relating to the river erosion. Similar phenomena were demonstrated at the Sansukezawa landslide. Study on the Juniko landslide suggests its occurrence may be divided into the northern and southern parts associated with flowing and slump mechanism, respectively.

研究分野：砂防学

キーワード：landslide　river incision　Shirakami-Sanchi

１．研究開始当初の背景

(1) Understanding the potential locations and behaviors of large landslides in wide area can be used for geomorphic hazard assessments and protection of natural environment. These unstable slopes prior to collapse are possibly to be connected to lithological predisposition such as bedding planes, foliation, or faults and fractures (Nichol et al., 2002). Among these, the number of fractures and/or faults may develop and propagate that play a significant role in formation of the gravitational failure associated with long-term river incision (Chigira and Tsou et al., 2013; Hou et al., 2014).Therefore, landslides must be interpreted from the view point of geology as well as regional landscape evolution, because which create a topographic setting of these landslides over wide area. However, the effects of fluvial incision history on landslide have only been reported in a limited number of papers (Hou et al., 2014; Tsou et al., 2014; Tsou et al., 2015).

(2) Large scale landscape evolution is important as well as detailed topographic features, because landslide that precedes failure is induced by fluvial erosion in a long term, but studies on river erosion into bedrock have largely been focusing on vertical incision. Yet variations in lateral river erosion may significantly incise channel bank and decrease slope stability. Consequently, the study addresses the gap and investigates the effects of vertical and lateral river incision on hillslope and incorporate them for identification of susceptible slopes.

２．研究の目的

(1) The Shirakami-Sanchi is deeply incised to form V-shaped inner valleys. Meandering river channels are inherited as channels maintain their sinuous shape during down-cutting. Widespread large landslides are commonly on the side slope of inner valleys that are undercut and appear to be destabilized by meandering river channels. The inherently weak geological characteristics of sedimentary and volcanic rocks of Miocene ages have played a predisposing role in relation to landslide genesis (Yagi et al., 2004) and have made the area fundamentally a very fragile mountain. Devastating slope failures triggered by earthquakes, rainstorms, and snowmelt are scattered throughout the catchment, but are rarely documented (e.g. Yagi et al., 2004; Higaki et al., 2011). The focus here is to constrain the response of mountain slope adjustment to fluvial processes for understanding how, when and with what characteristics slope failures may occur.

３．研究の方法

(1) Geological and topographic characteristics of landslides aligned along the Okawa River and the Juniko landslide were investigated. Field surveys were made using PRISM images with a resolution of 2.5 m, aerial photographs, and an airborne LiDAR-derived digital elevation model (DEM) of 1-m resolution acquired in 2008.

４．研究成果

(1) Digital surface model (DSM) and orthomosaics at 6.5 cm resolution from UAV imagery obtained in 2017 using structure-from-motion (SfM) photogrammetric procedures was constructed. Then, the DSM was resampled to a 1-m resolution and was used to compare to the 1-m LiDAR DEM to constrain the landslide magnitude and direction of the displacement vectors. This was studied at landslides along the right bank of the Okawa River (Fig. 1) using CIAS (the Correlation Image Analysis Software; Kääb and Vollmer, 2000). Results were also compared with longitudinal profiles collected by a hand-held laser-ranger finder. The computed horizontal displacements range from 0.1 to 9.7 m with a standard deviation of 1.81 m (Fig. 2). At the landslide body of the northern landslide the computed vectors suggest a southward movement, however, the explanation for this movement is currently unknown (Fig. 2). The longitudinal displacement for a flat, terrace-like topography of 6×7 m within the landslide body of the southern landslide was computed of ~7 m (Fig. 3) that is appropriately represented as compared with the filed measurement. Active displacements were generally constrained at the secondary and side scarps (3-9 m) and the edges of toes (2-8 m), where the retreating movements are well identified by the algorithm (Fig. 2). The retreat of landslide toes was likely triggered by lateral river erosion based on the interpretation of changes of river courses by aerial photos (Fig. 2) and an outcrop exposed on the landslide toe that consist of imbricated,

horizontally bedded gravels. Our results indicate that a combination of UAV-based SfM data and available DEM and the image correlation algorithm is useful and effective to understand the landslide dynamics.

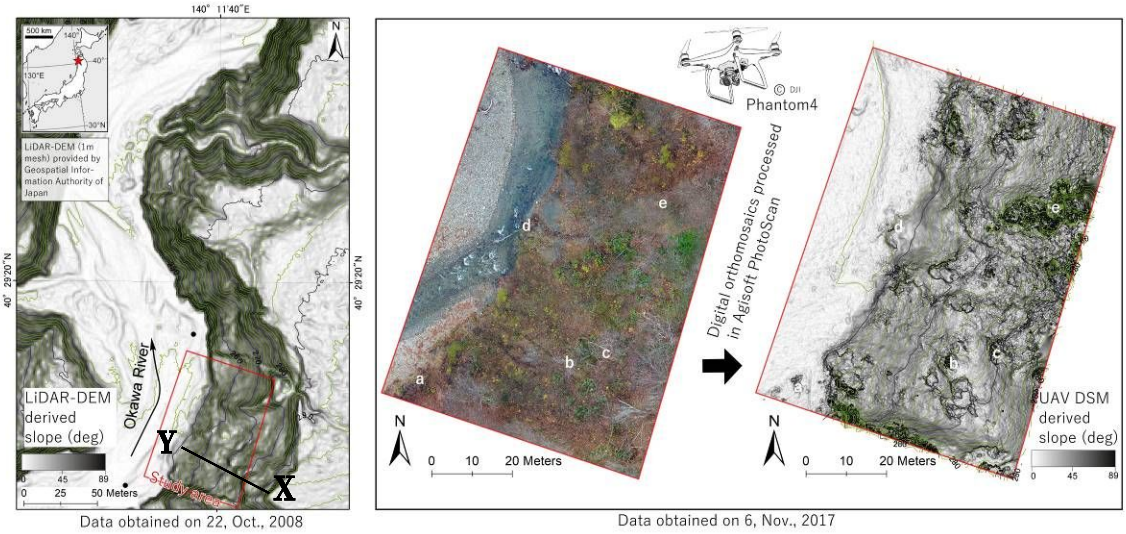

Fig. 1 Study area (landslides at the right bank of the Okawa River) and the slope image generated from the airborne LiDAR-derived DEM in 2008 and UAV-derived DSM on 2017. The XY cross section is indicated in Fig. 3.

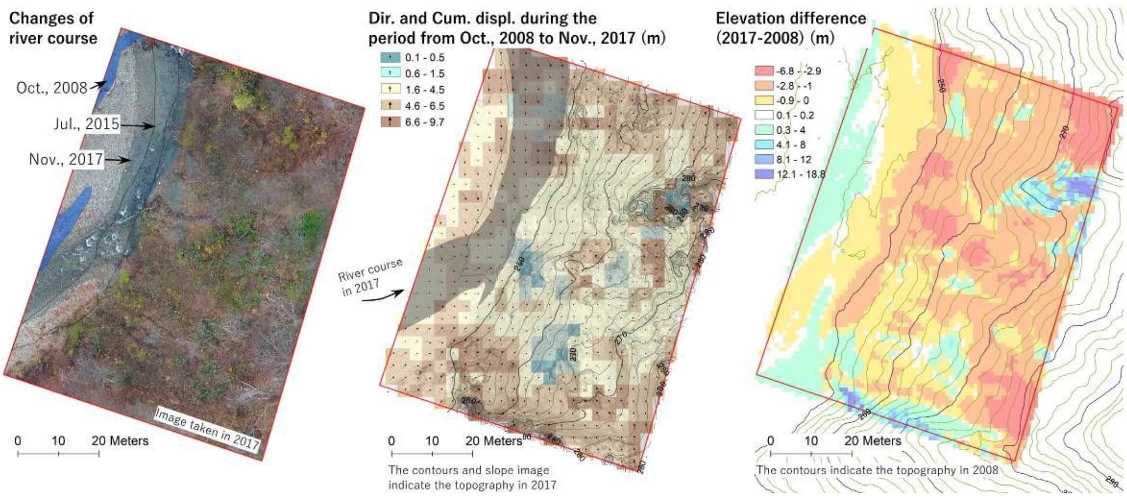

Fig. 2 Changes of river courses, direction and cumulative displacements, and elevation difference of the study area.

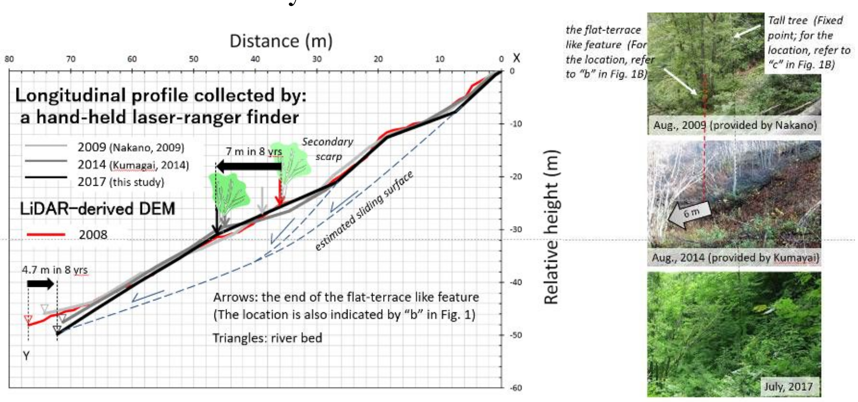

Fig. 3 Variations of the cross section (XY) from 2008 to 2017. The cross section is indicated in Fig. 1.

(2) The Juniko landslide with volume of ~10^8 m^3 is one of the largest landslides in Japan featured by landslide-formed lakes. The landslide was historically recorded triggered by an earthquake in 1704 (Tsugaruhanniki), but no direct information on its behavior is available. This study attempted to elaborate the Juniko landslide and look for additional

data and further analysis on the sliding mechanism. Results of a geological and geomorphological investigation of the landslide and dating data to examine the timing of the landslide occurrence were presented. Andesite tuff blocks range in various sizes and their associated debris deposits are the mass material that appears to deposit on beds of pumice-tuff (Fig. 4). The debris deposits, of the northern part (A), produced hummocks and NW-trending lobate ridges, that indicate a possible high-mobility associated with flowing mechanism during the landslide. In contrast to that of the northern part, the surface expression of the southern part (B) is characterized by series of uphill-facing scarps and pull-apart zones. The features are indicative of several slump blocks (Fig. 5). These observations suggest that the occurrence of the Juniko landslide may be divided into the northern and southern parts associated with different mechanism. Radiocarbon dating of the two wood fragments yielded ages of 290±30 (TNH231-FH) and 370±30 cal yr B.P. (TNH-232-FK), respectively. The estimated ages agree well with the occurrence of the earthquake.

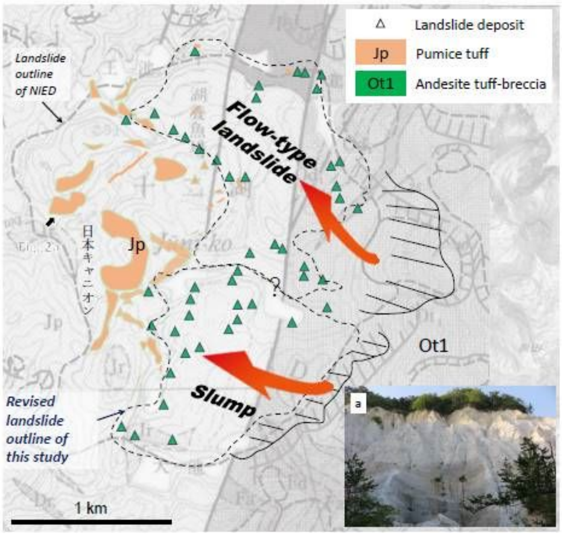

Fig. 4 Areal distribution of surficial geology of the landslide. The results were plotted on a geological map at a scale of 1:50,000 of Moritani (1968).

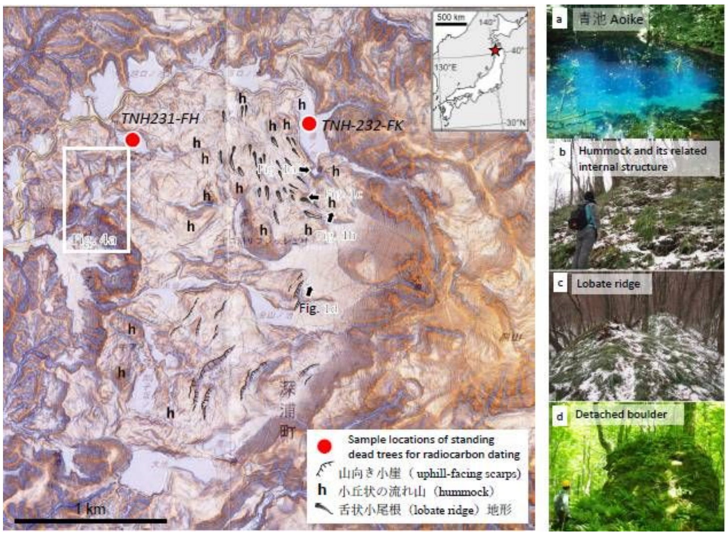

Fig. 5 Morphological features of the landslide. The results were plotted on a INYOU-ZU, provided by Aero Asahi Corporation, derived from the 1 m LiDAR-DEM.

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５．主な発表論文等

〔雑誌論文〕（計　　件）

〔学会発表〕（計４件）

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〔図書〕（計　　件）

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〔その他〕
ホームページ等

６．研究組織

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