Detection of the ground surface deformation by InSAR analysis at Kuchisakamoto landslide

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SAR Interferometry (InSAR) is one of the methods measuring small-scale ground surface deformation such as landslides and land subsidence. However, InSAR is a relatively new technique and factors affecting the accuracy of analysis are not well understood. We conducted accuracy validation of InSAR analysis using ALOS and ALOS2 images by comparing with in-situ GPS observation data in the Kuchisakamoto landslide in Shizuoka prefecture, central Japan. Additionally, we calculate annual average deformation rate by stacking method using interference images with high accuracy. Comparison of InSAR analysis results with GPS observation data showed that 17 in 97 ALOS and 4 in 6 ALOS2 interference images had high accuracy with error ≤20 mm. By comparing errors in the InSAR analysis and SAR observation conditions, four factors likely increased errors in InSAR analysis: (i) baseline decorrelation affected by long perpendicular baseline, (ii) temporal decorrelation affected by long observation period, (iii) noise associated with observation mode conversion, and (iv) phase unwrapping error that sometimes occur when ground deformation is large . Deformation rate map calculated using stacking method showed that some sub-blocks of landslide with large ground surface deformation existed in the main landslide block.

Keywords: landslide, InSAR

Topographical interpretation of landslides using a constant vertical exaggeration stereoscopic map

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This study introduces the method for interpreting landslide topographies with a constant vertical exaggeration stereoscopic (CVES) map. The map created by using digital elevation model (DEM) data shows 3D images of landforms as an anaglyph. We created two types of CVES maps by using the light detection and ranging (LiDAR) digital terrain model (DTM) and the Advanced Land Observing Satellite (ALOS) World 3D (AW3D) digital surface model (DSM) data (observation data from the Japanese satellite ALOS-Daichi) around Mt. Ebiradake in Northern Japanese Alps. We then compared these maps with a landslide distribution map created using air-photo interpretation. As a result, we could clearly identify scarps, which were formed on the landslide body due to secondary landslide activity and were several meters high on the CVES map created using LiDAR DEM data with 5 m resolution. A number of scarps identified on the CVES map were difficult to interpret using the air-photo technique. The CVES map provides very helpful data for creating high-resolution landslide distribution maps. In contrast, it was difficult to detect those scarps on the CVES map that were created from AW3D DSM data with 5 m resolution. However, we could identify landslides more than 200 m width and scarps more than 10-20 m high on the landslide body. The AW3D data cover the entire world, so the CVES map created by using AW3D DSM is useful for areas where LiDAR data and / or air-photos are unavailable for generating landslide distribution maps.

Keywords: constant vertical exaggeration stereoscopic map, topographical interpretation, Ebiradake landslide

Late Pleistocene paleolakes formed by landslide activities on the eastern foot of Mt. Kushigata, the Koma Mountains, central Japan

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Landslide activities are important agent on shaping slopes and creating landscapes in mountain areas. For example, geomorphic changes by landslide often provide natural environments rich in diversity.

Slope development of Mount Kushigata seems to have been affected by landslides activities and deep-seated gravitational slope deformation on both its eastern and western sides under earthquake-prone humid environments during the late Quaternary. In particular, on the eastern piedmont areas facing to the subsiding Kofu Basin and the active Kushigatayama fault, many large landslide bodies with secondary landslide activities are commonly identified on the basis of our geomorphic classification.

In this area, thick lacustrine sediments and debris flow deposits bearing the Ontake Pm-1 tephra layer (95 ka) are seen at several locations with different altitudes. Basically, those lacustrine sediments blanket large landslide bodies. Thus paleolakes would have been developed on closed depressions and gentle slopes formed on such landslide masses around 95 ka.

The timing of emergence and extinction of paleolakes are not clear due to the paucity of chronological information of the lacustrine sediments yet. However, those paleolakes were probably destructed and filled by valley head incision, secondary landsliding, and influx of debris from nearby slopes. Lacustrine sediments on the eastern face of Mount Kushigata demonstrate a portion of changing natural environments by landslide processes during the late Pleistocene.

Keywords: Tephrochronology, On-Pm1 tephra, lacustrine sediments, deep-seated gravitational slope deformation

Analysis of distribution of linear depressions based on decision-tree model in Kiso Mountain Range, central Japan

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Few studies have focused on mountain gravitational deformation in the sight of landform evolution. In this presentation, we discuss the relationship between linear depressions and (1) geomorphological processes and (2) geomorphological condition. We select the area of granodiorite (Geological Survey of Japan, AIST, 2015) in the northern part of Kiso Mountain Range.

Linear depressions, cirques and periglacial smooth slopes were classified based on Geospatial Authority Information of Japan (GSI) color aerial photographs. Cirques and periglacial smooth slopes were referred to Aoki (2000) and to Yanagimachi and Koizumi (1988) respectively. Landslides were based on landslide mass of landslide distribution map published by National Research Institute for Earth Science and Disaster Prevention. Drainage network and topographic data were obtained based on Fundamental Geospatial Data (10m mesh elevation) by GSI using ArcGIS10.2.2. We did decision-tree analysis using WEKA 3.6.13 (Hall et al., 2009) for investigating distribution of linear depressions. Explanatory variables are as follows: number of stream, average stream length, average stream gradient, average stream relative height, drainage density, stream bifurcation ratio, stream slope ratio, stream length ratio and drainage density ratio of each stream order, and maximum altitude, minimum altitude, relative height, stream length, stream gradient, drainage density, area, slope direction (East or West), slope direction (North or South), existence of glacier in Last Glacial Maximum, that of glacier in Younger Dryas, that of landslide mass and that of periglacial smooth slope in each unit drainage basin. Explained variables are two groups of unit drainage basins divided by density of linear depressions. Its value is 0.5 [km/km^2].

It is suggested that the characteristics of unit drainage basins with high density of linear depressions are as follows: (1) existence of landslide mass and (2) third-order stream with gradient greater than about 30 degree.

Keywords: Decision-tree, Linear depressions, Kiso Mountain Range, Mountain gravitational deformation, Geomorphological analysis

Frequency distribution of the deep-seated rapid landslide area in different events in the same region

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Deep seated rapid (catastrophic) landslide (hereafter DCL) often trigger debris flow and sometimes generate a landslide dam, and have sometimes had serious impacts on humans. Therefore, it is important to predict the scale of DCL to prevent and mitigate disasters due to DCL.
The scale of DCL should be strongly controlled by geological and geomorphological settings. Thus, in this study, it can be propose a hypothesis that the scale of DCL should be comparable to the past DCL in the same region. We tested this hypothesis using DCL inventories in Fuji river basin in Yamanashi and Totsu river basin in Nara, Japan. We prepared a map of ancient DCL scars through the interpretation of stereoscopic aerial photographs and evaluated the timing of each DCL occurrence by using multi-temporal DCL inventory map and various sets of aerial photographs. Then, we compiled 3 events and clarified the relationship between landslide area and frequency of DCL. Also, we identified shape of rock creep using high resolution slope map made by LiDAR data and clarified the relationship of area and frequency of rock creeps.
As a result, we found the similar scale characteristic in DCL of Fuji river basin for all events, although the landslides occurred in 1982 were slightly smaller compared to the rest of the event. In Totsu river basin, the scale characteristic of DCL occurred in 1911 and 2011 had almost similar trend. These results supported our hypothesis that there is the site-specific relationship between landslide area and frequency of DCL. Moreover, the scale of rock creep and DCL were almost similar, except DCL of 1982 in Fuji river basin. Long-lasting, small-scale mass movements called gravitational mass rock creeps sometimes lead to deep catastrophic sliding. So, it can be thought that the scale of DCL might be determined at the stage of long-lasting, small-scale mass movements before landslide occurrence, supporting the hypothesis that the scale of DCL should be controlled by geological and geomorphological settings.
These suggest that the scale of the future DCL will be equivalent to the scale which have occurred in the past in the same basin and it have might be related to the scale of rock creep.

Keywords: deep seated rapid landslide, landslide area, rock creep, LiDAR data, aerial photograph

Experiment for effects of preferential flow and entrapped air on slope failure

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Although many previous studies examined the mechanism that slope failure s concentrated around the rainfall peak, and the process that collapsed soil quickly tuned into debris flow, to date there is no widely used theory for describing these phenomena. Recent studies proposed possible explanation about the process of slope failure induced debris flow. Several processes explain drastic decline of safety factor with the increase of rainfall intensity have been proposed. According to filed observation for the landslide scars, a number of studies suggested that the preferential flow through soil pipe might effect on drastic decline of safety factor with the increase of rainfall intensity. Several studies confirmed that the preferential flow through soil pipe gave an impact on the redistribution of pore water pressure in soil layer. Also, other studies suggested that the drastic decline of safety factor can be influenced by the extra pore water pressure due to entrapped air in the soil layer.
Therefore, we conducted the artificial hillslope experiment to test the influence of the preferential flow thorough soil pipe and entrapped air on slope failure . Figure shows our experimental model. We set manometers in each 20 cm along the soil layer to monitor positive soil pore water pressure distribution at the bottom of soil layer. To examine the effect of entrapped air on slope failure occurrence, we used two ways, rainfall simulator and upper water tank, to supply water to the soil layer. Steel wire netting and cloth was attached between the soil layer and upper water tank to support the sand. For several cases, we didn’t use rainfall simulator, since we assumed that the if water was supplied only at the upper end of the hillslope, the pore air in soil layer easily went out. While, once the surface layer of hillslope was saturated, pore air might be entrapped in the soil layer. To enhance the saturation of surface layer, in several cases, we put shallow fine sand layer at the surface of hillslope.
To simulate soil pipes, we set the artificial soil pipe made by polyvinyl chloride tube, which was made holes (φ4 mm) in each 2 cm. To test the effect of water pressure in soil pipe, the upper end of the artificial soil pipe was connected to another water tank to control the water pressure in the upper end of the artificial soil pipe. Further, we attached gate valve at the intermediate of soil pipe to disturb water flow in soil pipe. So, we changed water levels in both upper water tank and water tank connected with soil pipe and monitor pore water pressure and displacement of hillslope. We found that slope failure occurred just after the increase of water pressure in soil pipe, indicating that water pressure in soil pipe strongly controlled slope failure occurrence and movement. Moreover, the effect of entrapped air was not obvious.

Keywords: slope failure, soil pipe, pore water pressure

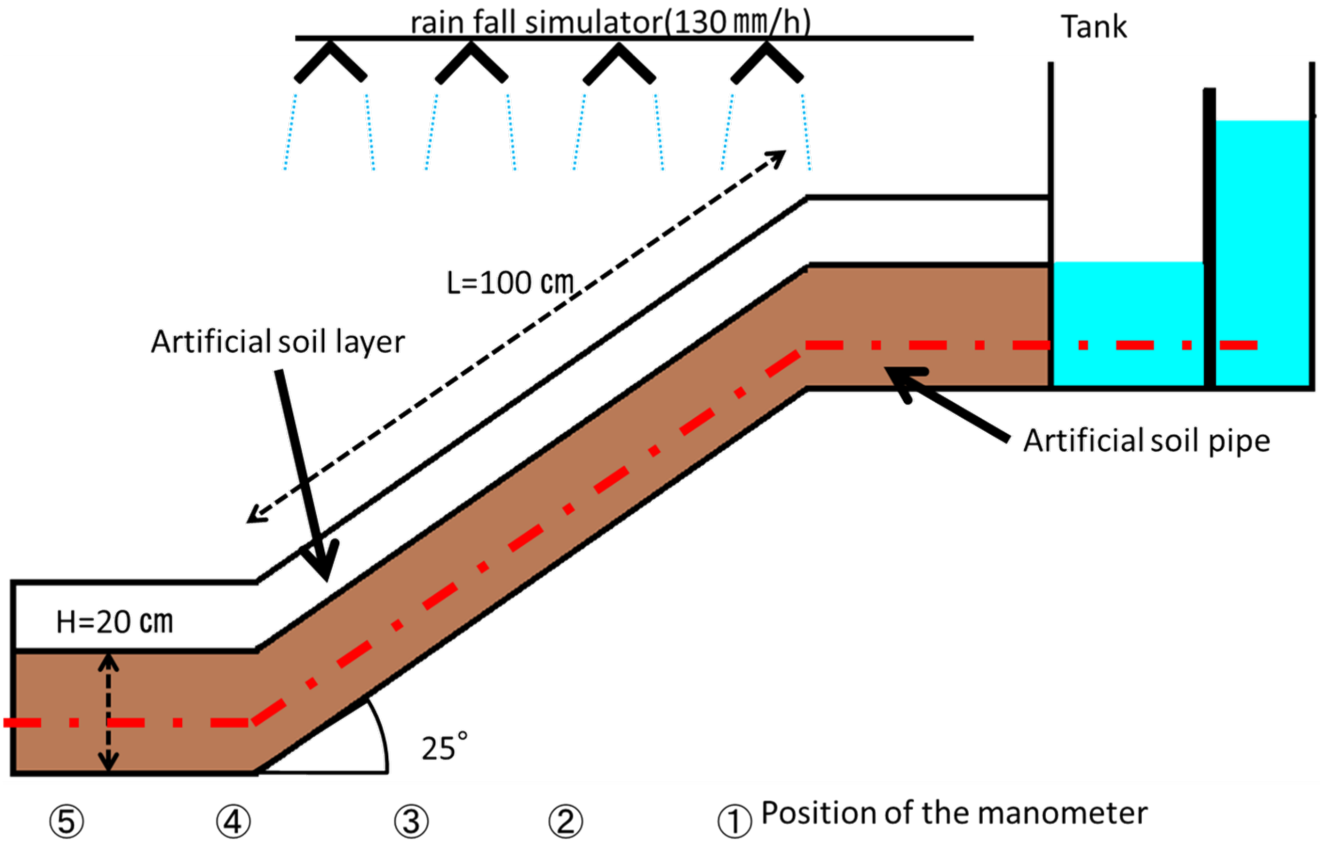

Figure experimental equipment

Study on the peak ground acceleration effect on the seismic landslide

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After the South Hyogo earthquake in 1995, a method assessing the risk of a slope failure caused by the earthquake has been examined, using slope gradient, curvature, and peak ground acceleration as evaluation factors.
Consequently in the South Hyogo earthquake case study and with identical topographic condition, we confirmed the rate of landslide linearly increased with the increase of the peak ground acceleration. On the basis of this tendency, a susceptibility assessment method was proposed and has been inflected.
On the other hand, strong ground acceleration was observed during recent earthquakes, such as 2004 Niigata Chuetsu earthquake and 2008 Iwate, Miyagi inland earthquake, large-scale landslide occurred frequently.
In areas where the peak ground acceleration has been very strong, it may be different from the relationship of the peak ground acceleration and landslide rate, which was confirmed by South Hyogo earthquake.
In this study, we examined the relationship of peak ground acceleration on landslide rate and landslide scale, including strong seismic motion areas. The area analyzed in this study is 700 km^2 which is the focal region of the 2004 Niigata Chuetsu earthquake. As preparations for analysis, we extracted the position of the landslide using GIS data produced through aerial photo interpretation. In addition, we calculated topographic features such as slope gradients using DEM data (10m mesh). This DEM data was made from the contour line before the earthquake. We calculated the area rate of the landslide every 100 gal of peak ground acceleration, and every 5 degrees of slope gradient.
As a result, the relationship between slope gradient (*Slope*) and the rate of landslide area (*P*) can be explained with equation 1, in any range of peak ground acceleration. During the peak ground acceleration division the degree of leaning was almost maintained the same (around 0.1).
The intercept of the equation increased so that the peak ground acceleration of the earthquake became strong.
$\ln(P) = a \times Slope + b$ eq. 1
In this case the intercept *b* can become the function of the peak ground acceleration of the earthquake.
Subsequently, landslides were divided into two groups in terms of landslide area. We investigated relations such as the peak ground acceleration, slope gradient, slope curvature and landslide scale.
The result shows that, on the same slope gradient, the lower threshold of the maximum acceleration for the large-scale landslide (area> 1 ha) occurrence is 100 ~ 250 gal larger than that of small-scale landslide. Moreover, the threshold acceleration for large-scale landslide on convex slope was smaller 20 ~ 60 gal smaller than that of the concave slope.

Keywords: Landslide, Peak ground Acceleration, Slope gradient, Earthquake

